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MCDONNELL DOUGLAS

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SPACE STATION PROGRAM (MODULAR) COST ESTIMATES DOCUMENT VOLUME II

Subsystem Estimates

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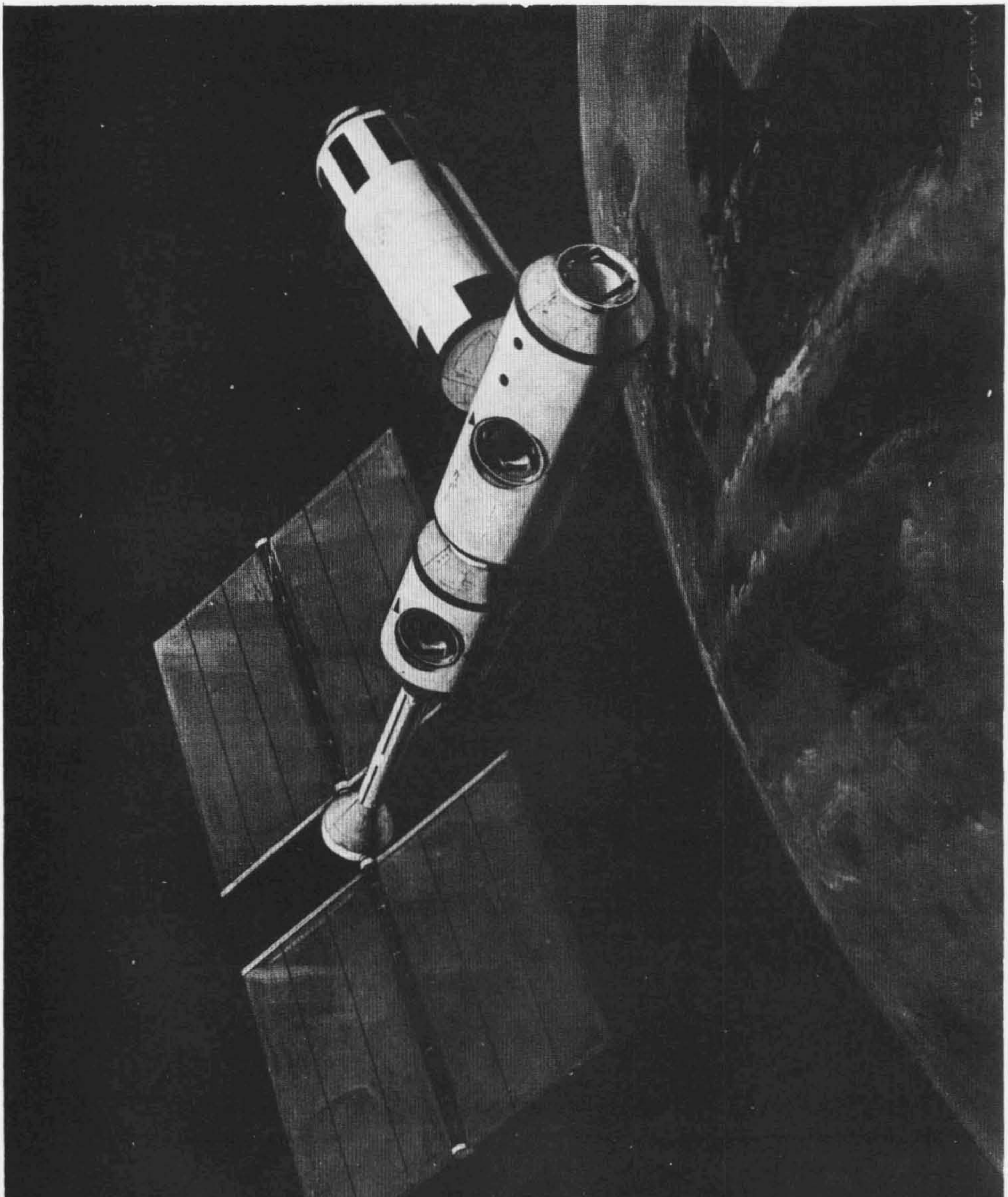

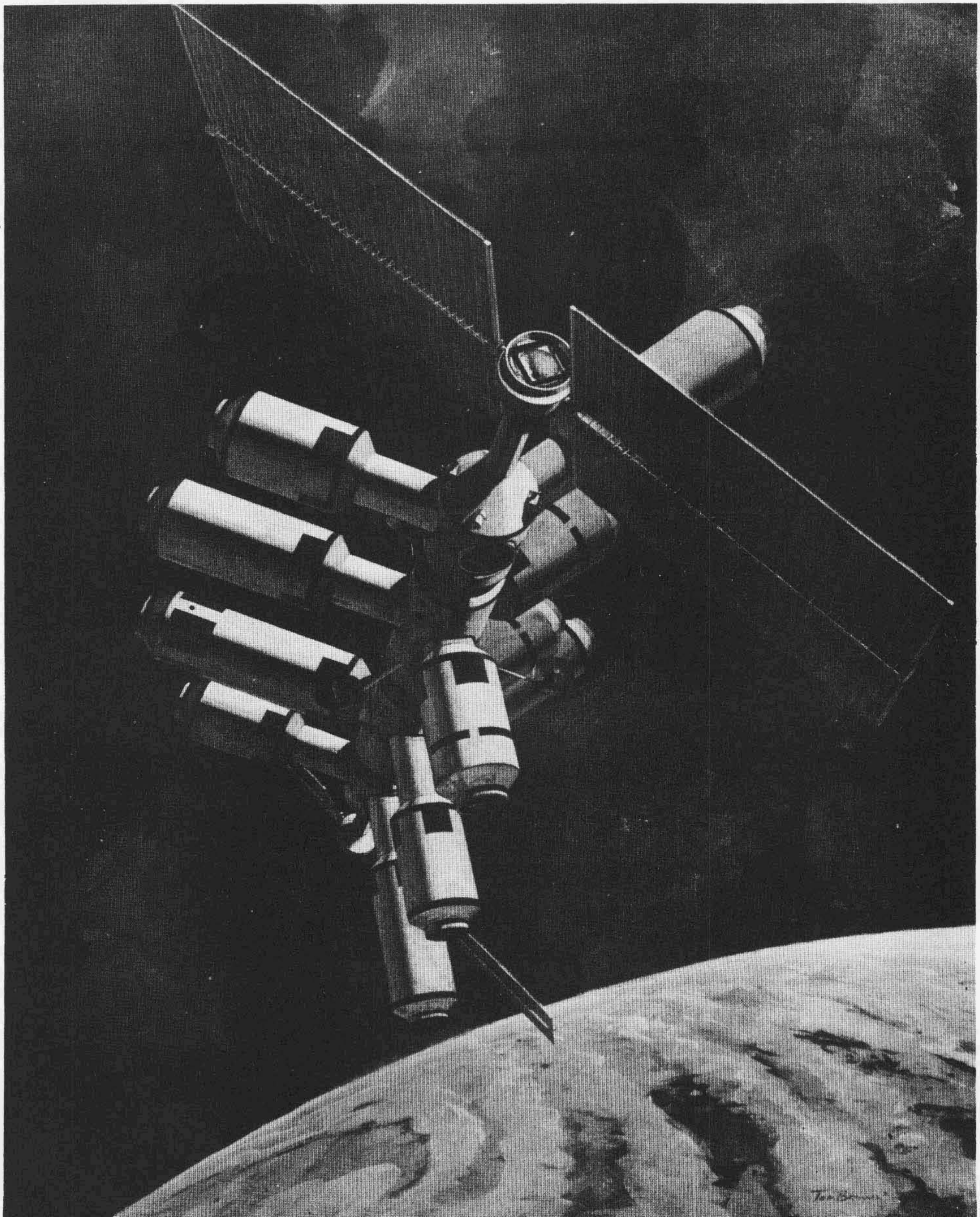

PREFACE

Work reported herein was performed under the Space Station Phase B Extension Period Study (Contract NAS8-25140). The purpose of the Space Station Extension Period has been to perform the Phase B definition of the Modular Space Station. The modular program selected during the option period (low initial cost, incremental manning) was evaluated, requirements defined, and program definition and design accomplished to the depth necessary for exit from Phase B. The initial 2-1/2 months effort of the extension period was for analyses of the requirements associated with Modular Space Station program options. During this period, a baseline incrementally manned program has been derived with attendant experiment program options. In addition, those features of the program that significantly affect the initial development and early operating costs were identified, and their impact on the program were assessed. This assessment, together with a recommended program, were submitted for NASA review and approval on 15 April 1971. The second phase of the study (15 April to 3 December 1971) consists of the program definition and preliminary design of the approved Modular Space Station configuration.

This report is submitted as part of DRL No. MF-01, "Space Station Program (Modular) Cost Estimates Document" which consists of the following volumes:

- Volume I —Program Estimates
- Volume II—Subsystem Estimates

Volume I, Program Estimates, contains the program, project, and system level cost and schedule data.

Volume II, Subsystem Estimates, contains the subsystem cost and schedule data as well as the appendices (WBS Task Descriptions and Cost Estimate Data Form A).

DATA REQUIREMENTS (DR's)
MSFC-DPD-235/DR NOs.
(Contract NAS8-25140)

Category	Designation	DR Number	Title
Configuration Management	CM	CM-01	Space Station Program (Modular) Specification
		CM-02	Space Station Project (Modular) Specification
		CM-03	Modular Space Station Project, Part I, CEI Specification
		CM-04	Interface and Support Requirements Document
Program Management	MA	MA-01	Space Station Phase B extension Study Plan
		MA-02	Performance Review Documentation
		MA-03	Letter Progress and Status Report
		MA-04	Executive Summary Report
		MA-05	Phase C/D Program Development Plan
		MA-06	Program Option Summary Report
Manning and Financial	MF	MF-01	Space Station Program (Modular) Cost Estimates Document
		MF-02	Financial Management Report
Mission Operations	MP	MP-01	Space Station Program (Modular) Mission Analysis Document
		MP-02	Space Station Program (Modular) Crew Operations Document
		MP-03	Integrated Mission Management Operations Document
System Engineering and Technical Description	SE	SE-01	Modular Space Station Concept
		SE-02	Information Management System Study Results Documentation
		SE-03	Technical Summary
		SE-04	Modular Space Station Detailed Preliminary Design
		SE-06	Crew/Cargo Module Definition Document
		SE-07	Modular Space Station Mass Properties Document
		SE-08	User's Handbook
		SE-10	Supporting Research and Technology Document
		SE-11	Alternative Bay Sizes

SUBJECT REFERENCE MATRIX

LEGEND:

- CM Configuration Management
- MA Program Management
- MF Manning and Financial
- MP Mission Operations
- SE System Engineering and Technical Description

	CM				MA		MF	MP			SE								
	CM-01 Space Station Program (Modular) Specification	CM-02 Space Station Project (Modular) Specification	CM-03 Modular Space Station Project Part I CEI Spec	CM-04 Interface and Support Requirement Document	MA-05 Phase C/D Program Development Plan	MA-06 Program Option Summary Report	MF-01 Space Station Program (Modular) Cost Estimates Document	MP-01 Space Station Program (Modular) Mission Analysis Document	MP-02 Space Station Program (Modular) Crew Operations Document	MP-03 Integrated Mission Management Operations Document	SE-01 Modular Space Station Concept	SE-02 Information Management System Study Results	SE-03 Technical Summary	SE-04 Modular SS Detailed Preliminary Design	SE-06 Crew/Cargo Module Definition Document	SE-07 Modular Space Station Mass Properties Document	SE-08 User's Handbook	SE-10 Supporting Research and Technology	SE-11 Alternate Bay Sizes
2.0 Contractor Tasks																			
2.1 Develop Study Plan and Review Past Effort (MA-01)																			
2.2 Space Station Program (Modular) Mission Analysis								●											
2.3 Modular Space Station Configuration and Subsystems Definition														●					
2.4 Technical and Cost Tradeoff Studies							●												
2.4.4 Modular Space Station Option Summary											●								
2.5 Modular Space Station Detailed Preliminary Design														●					
Mass Properties																●			
2.6 Crew Operational Analysis									●										
2.7 Crew Cargo Module															●				
Mass Properties																●			
2.8 Integrated Mission Management Operations										●									
2.9 Hardware Commonality Assessment													●						
2.10 Program Support					●														
2.11 Requirements Definition																			
Space Station Program (Modular)	●																		
Space Station Project (Modular)		●																	
Modular Space Station Project–Part 1 CEI			●																
Interface and Support Requirements				●															
2.12 Plans					●														
2.13 Costs and Schedules							●												
2.14 Special Emphasis Task Information Management (IMS)												●							
Modular Space Station Mass Properties																●			
User's Handbook																	●		
Supporting Research and Technology																		●	
Technical Summary													●						
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Section 1
INTRODUCTION

1.1 BACKGROUND

With the advent of the Space Shuttle in the late 1970's, a long-term manned scientific laboratory in Earth orbit will become feasible. Using the shuttle for orbital buildup, logistics delivery, and return of scientific data, this laboratory will provide many advantages to the scientific community and will make available to the United States a platform for application to the solution of national problems, such as ecology research, weather observation and prediction, and research in medicine and the life sciences. It will be ideally situated for Earth and space observation, and its location above the atmosphere will be of great benefit to the field of astronomy.

This orbiting laboratory can take many forms and can be configured to house a crew of up to 12 men. The initial study of the 33-foot-diameter Space Station, launched by the Saturn INT-21 and supporting a complement of 12 crewmen, has been completed to a Phase B level and documented in the DRL-160 series. Recently completed studies are centered around a Space Station comprised of smaller, shuttle-launched modules. These modules could ultimately be configured to provide for a crew of the same size as on the 33-foot-diameter Space Station, but buildup would be gradual, beginning with a small initial crew and progressing toward greater capability by adding modules and crewmen on a flexible schedule.

The Modular Space Station, Phase A level, study results are documented in the DRL-231 series. Recent Modular Space Station Phase B study results are documented in the DPD-235 series, of which this is a volume.

The Space Station will provide laboratory areas, which like similar facilities on Earth, will be designed for flexible, efficient changeover as research and experimental programs proceed. Provisions for such functions as data processing and evaluation, astronomy support, and test and calibration of optics will be included in the laboratory areas. Zero gravity, which is desirable for the conduct of experiments, will be the normal mode of operation. In addition to experiments carried out within the station, the laboratories will suppport operation of experiments in separate modules that are either docked to the Space Station or free-flying.

Following launch and activation, Space Station operations will be largely autonomous, and an extensive ground support complex will be unnecessary. Ground activities will ordinarily be limited to long-range planning, control of logistics, and support of the experiment program

The Initial Space Station (ISS), which is shown in the first frontispiece, will be delivered to orbit by three Space Shuttle launches and will be assembled in space. A crew in the shuttle orbiter will accompany the modules to assemble them and check interfacing functions.

ISS resupply and crew rotation will be carried out via round-trip shuttle flights using Logistics Modules (Log M's) for transport and on-orbit storage of cargo. Of the four Log M's required, one will remain on orbit at all times.

The shuttle will deliver experiment modules to the Space Station, as required by the experiment program. On return flights, the Shuttle will transport data from the experiment program, returning crewmen, and wastes.

The Power/Subsystems Module will be launched first, followed at 30-day intervals by the Crew/Operations Module and the General Purpose Laboratory (GPL) Module. This basic ISS configuration will provide for a crew of six. Subsequently, two additional modules (duplicate Crew/ Operations and Power/Subsystems Modules) will be mated to the ISS to form the Growth Space Station (GSS) (shown in the second frontispiece), which will house a crew of 12 and provide a capability equivalent to the 33-foot INT-21-launched Space Station. GSS logistics support will use a Crew Cargo Module capable of transporting a crew of six.

During ISS operations, five Research Applications Modules (RAM's) will be assembled to the Space Station. Three of these modules will be returned prior to completion of the GSS. In the GSS configuration, 12 additional RAM's will augment the two remaining from the ISS phase. Three of the RAM's delivered to the GSS will be free-flying modules.

During the baseline 10-year program, the Space Station will be serviced by shuttle-supported Logistics Module or Crew Cargo Module flights.

1.2 SCOPE OF THIS VOLUME

The program and subsystem cost estimates and schedules in these volumes have been prepared in accordance with the Modular Space Station Program Definition (Phase B) Statement of Work, which calls for costs and schedules to be prepared for the Modular Space Station Program, beginning with Phase C and D implementation and continuing through the flight operations phase of the program. All data were to be prepared at the appropriate levels and were to be consistent with the Work Breakdown Structure (WBS), Figure 1-1.

The level of definition varied for the different elements and phases of the program; therefore, the costs and schedules data varied as well. The costs and schedules of all elements and phases were reported at the project, Level 3, and summarized to the program Level 2. The Space Station Project (ISS phase—first 5 years of operation) was reported to the system Level 4, and the (ISS) Space Station Modules system was reported to the subsystems Level 5, as indicated in the Space Station Project (ISS only) WBS breakdown, Figure 1-2.

Volume I, Program Estimates, contains the program, project and system level cost, and schedule data.

Volume II, Subsystem Estimates, contains the subsystem cost and schedule data, and the appendixes (WBS Task Descriptions and Data Form A).

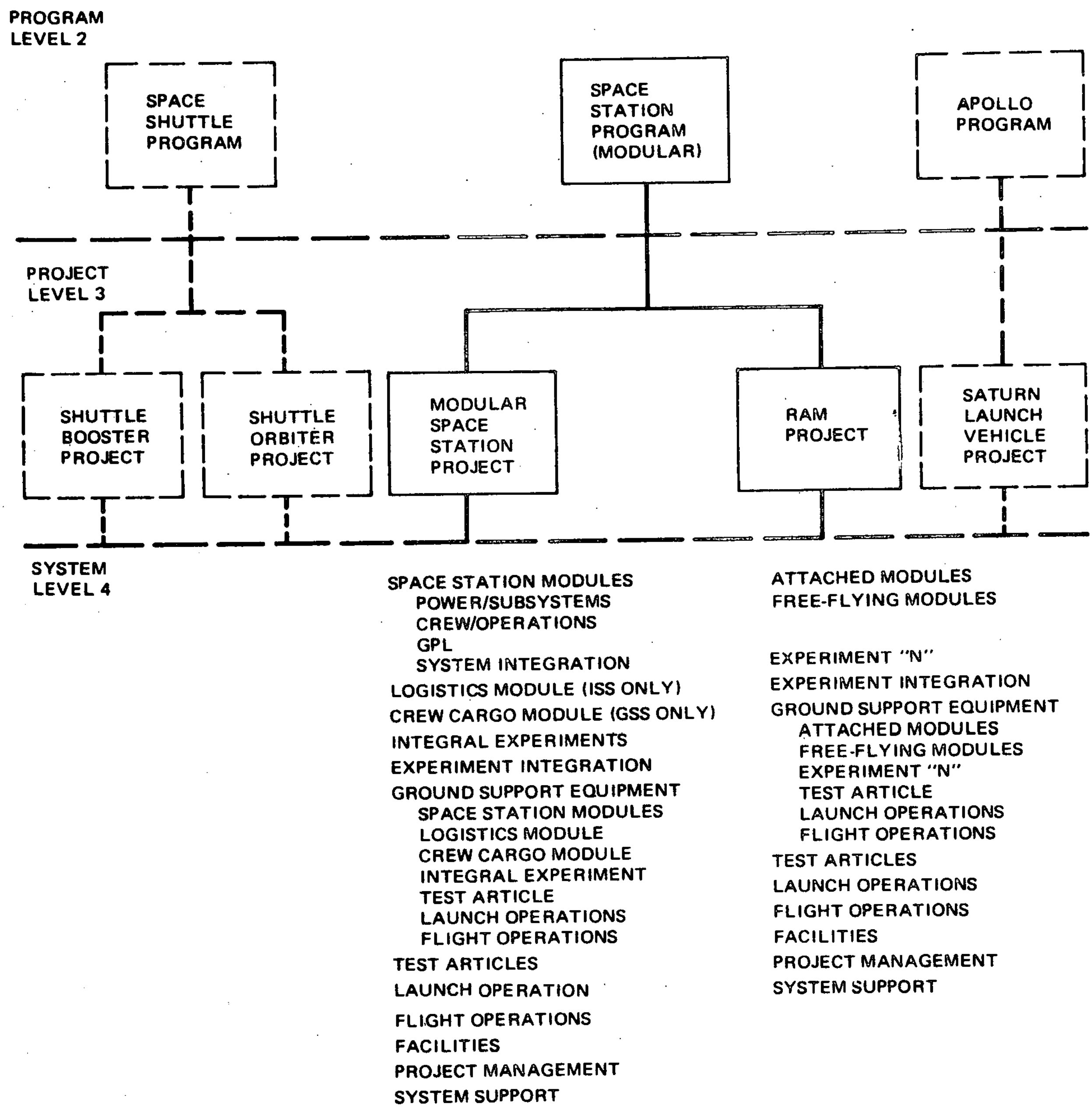


Figure 1-1. Work Breakdown Structure for Space Station Program (Modular)

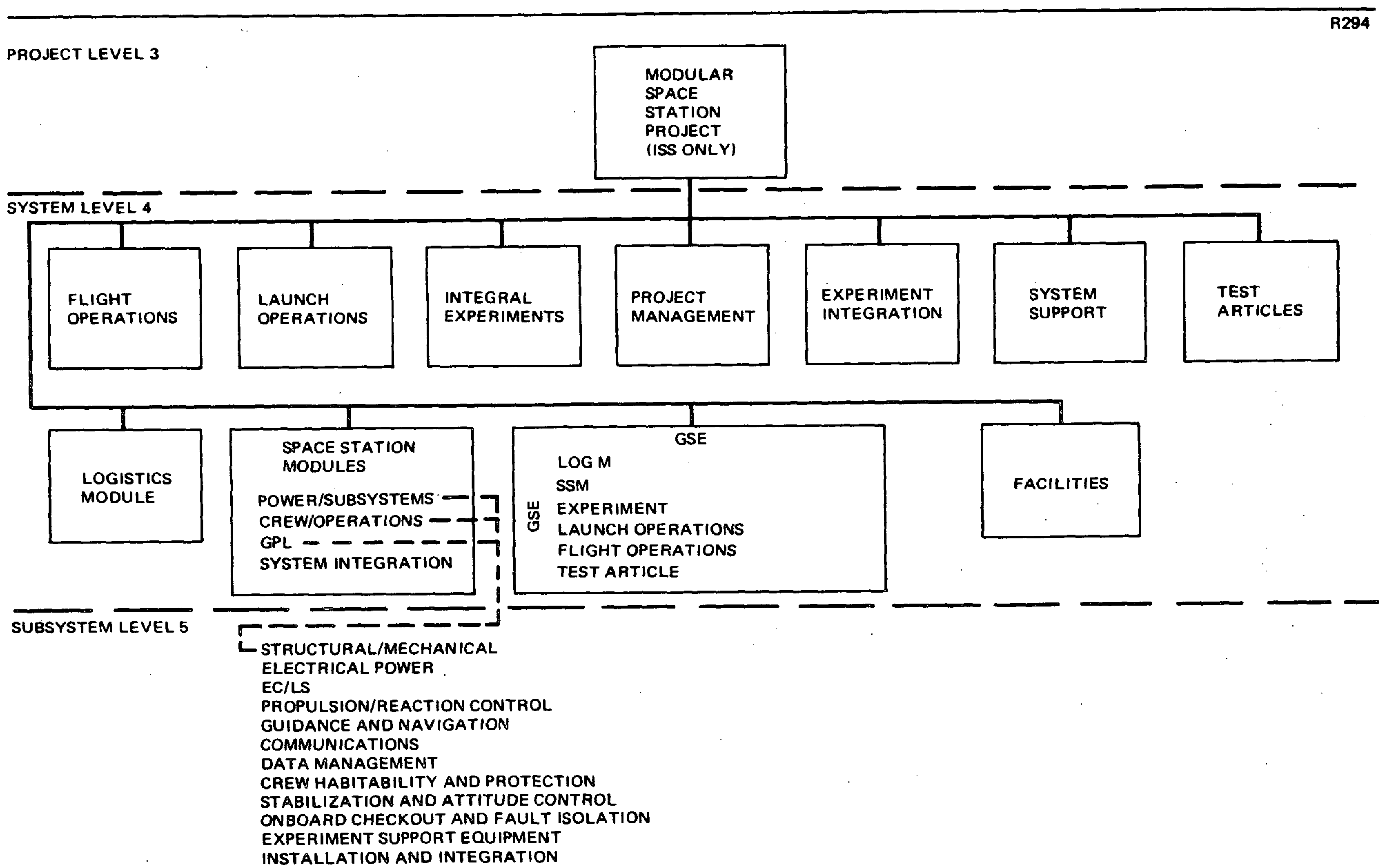


Figure 1-2. Work Breakdown Structure for Space Station Project (ISS Phase)

Section 5

SUBSYSTEM LEVEL 5 - TOTAL SUBSYSTEMS FOR SPACE STATION MODULES - SPACE STATION PROJECT—ISS ONLY

The Space Station Modules System is composed of the following subsystems, which are defined in Appendix A:

- Structural and Mechanical
- Electrical Power
- Environmental Control and Life Support
- Propulsion and Reaction Control
- Guidance and Navigation
- Communications
- Data Management
- Crew Habitability
- Stabilization and Attitude Control
- Onboard Checkout and Fault Isolation
- Experiment Support Equipment
- Installation and Integration

The subsections that follow contain a cost summary and a development and production schedule for each subsystem. These cost estimates were developed at the subassembly and component levels, in consonance with the technical definitions, quantities, and location in the individual modules. The cost of each subsystem includes the cost of spares as follows.

Subsystem	Spares as a Percent of Total Subsystem Cost		
	Production Spares (%)	Operations Spares (%)	Total Spares (%)
Structural and Mechanical	0.1	2.1	2.2
Electrical Power	1.0	119.0	120.0
Environmental Control and Life Support	1.0	145.0	146.0
Propulsion and Reaction Control	1.0	95.0	96.0
Guidance and Navigation	1.0	100.0	101.0
Communications	0.5	110.0	110.5
Data Management	0.5	105.0	105.5
Crew Habitability	1.0	95.0	96.0
Stabilization and Attitude Control	0.1	140.0	140.1
Onboard Checkout and Fault Isolation	5.0	78.0	83.0
Experiment Support Equipment	0.1	95.0	95.1

Equivalent quantities of development test and qualification test shipsets for each subsystem are tabulated in Table 5-1. It is noted that test article costs assume that development test articles will be refurbished for reuse, as possible, in the functional model, and that qualification test articles will be refurbished, as possible, for reuse in the flight integration tool. (Reference: Test article "N" definition in Appendix A.)

Each of the subsystem schedules shows design, development, test, and manufacturing requirements. The Space Station module subsystem level activities presented include design engineering; subsystem development test, qualification test, and deliveries; and operational vehicle manufacturing requirements.

The composite subsystem development and qualification test time spans are established, based on the Space Station module system level time requirements as constrained by the program phase durations. The individual subsystem development and qualification testing is performed initially during the test time-spans allocated. Subsystem integration testing in the functional model (FM) and flight integration tool (FIT) is then performed at the Space

Table 5-1

SPACE STATION MODULES SUBSYSTEMS, EQUIVALENT DEVELOPMENT QUANTITY (SHIPSETS)*

WBS	Subsystem	Development Test	Qualification Test
8x24	Electrical Power	0.8	1.2
8x05	EC/LS	0.5	0.4
8x59	Crew Habitability and Protection	0.4	0.4
8x23	Propulsion and Reaction Control	0.5	0.5
8x47	Data Management	0.4	0.4
8x56	Stabilization and Attitude Control	0.5	0.5
8x46	Guidance and Navigation	1.0	1.2
8x07	Communications	0.5	0.6
8x57	On-Board Checkout and Fault Isolation	0.2	0.2
8x02	Structural and Mechanical	0.2	0.8
8x39	Experiment Support Equipment	0.8	1.0

*Shipset is Space Station Modules equivalent (three modules' worth)

Station module system level. Subsystem integration tests are predicated on the concept that all subsystems must demonstrate their capability to operate as systems without adverse interactions or deleterious side effects. Until this demonstration is made, the subsystems cannot be considered fully qualified. This philosophy also applies to existing hardware that has been repackaged or slightly modified to meet new requirements.

Development tests are performed to determine and evaluate design feasibility, functional parameters, technical data, packaging and fabrication techniques, and environmental limitations. This category of testing includes tests designed to demonstrate that the design meets the specified requirements, to identify critical areas where design improvement may be required, or to identify primary failure modes or critical environments. They are also used to demonstrate that the probability of passing qualification is sufficiently high to warrant commitment of equipment to the qualification test. These tests may be conducted at any hardware or software level, and they include compatibility or integration tests. The qualification tests are performed to demonstrate specification compliance.

A schedule for each of the subsystems is presented in the following sections. The number of equivalent subsystems is based upon the data in Table 5-2. The quantity shown in the columns "FM" and "FIT" indicates the total equivalent quantity of the subsystem units required to support the FM or FIT. The subsystem equipment for the FM and FIT comes from the subsystem development test and the qualification test, respectively. The quantity shown in the columns "Additional to FM" or "Additional to FIT" is the amount required in addition to that received from the subsystem development test or qualification test. The one exception to this is in the structural and mechanical subsystem, where the quantity for the FIT is a nonqualification unit.

Table 5-2

SPACE STATION MODULES, TEST ARTICLE "N"—SUBSYSTEM EQUIVALENT EQUIPMENT LIST

(ISS Only)

	Development Test	Qualification Test	FM	Additional to FM	FIT	Additional to FIT	Operational Vehicle	Spares		Total
								FIT	OV	
Electric Power	0.8	1.2	0.7	0.2	0.8	0.2	1.0	0.23	0.85	4.48
Environmental control and life support	0.5	0.4	0.2	0	1.0	0.8	1.0	0.2	0.71	3.61
Crew habitability and protection	0.4	0.4	0.1	0	0.9	0.7	1.0	0.16	0.36	3.02
Propulsion and reaction control	0.5	0.5	0.9	0	0.9	0.6	1.0	0.028	0.701	3.329
Data management	0.4	0.4	0.9	0.7	1.0	0.8	1.0	0.705	0.905	4.910
Guidance, navigation, and control	1.0	1.2	0.6	0.1	0.4	0	1.0	0.131	0.901	4.332
Onboard checkout and fault isolation	0.2	0.2	0.8	0.6	1.0	0.9	1.0	0.36	0.68	3.94
Structural and mechanical	0.2	0.8	0	0	0.9	0	1.0	0.001	0.015	2.016
Experiment support equipment	0.8	1.0	0.6	0.2	1.0	0.5	1.0	0.36	0.701	4.561
Stability and attitude control	0.5	0.5	0.4	0	0.5	0.2	1.0	0.084	0.901	3.185
Communications	0.5	0.6	0.6	0.2	0.5	0.2	1.0	0.284	0.705	3.489

5.1 STRUCTURAL/MECHANICAL SUBSYSTEM (WBS 2 x 75 x 02)

5.1.1 Summary

The structural and mechanical subsystem includes:

A. The basic structure and all provisions for the structural accommodation of a six-man crew, the spacecraft subsystems, and an experiment program.

B. Mechanical equipment required for:

1. Docking with experiment or logistics modules.
2. Space Station access, including hatches, airlocks, and viewports.
3. Antenna and solar array drive.
4. Cargo handling and transfer.
5. Extravehicular activity support.

This subsystem is illustrated in the WBS assembly-level breakdown in Figure 5-1.

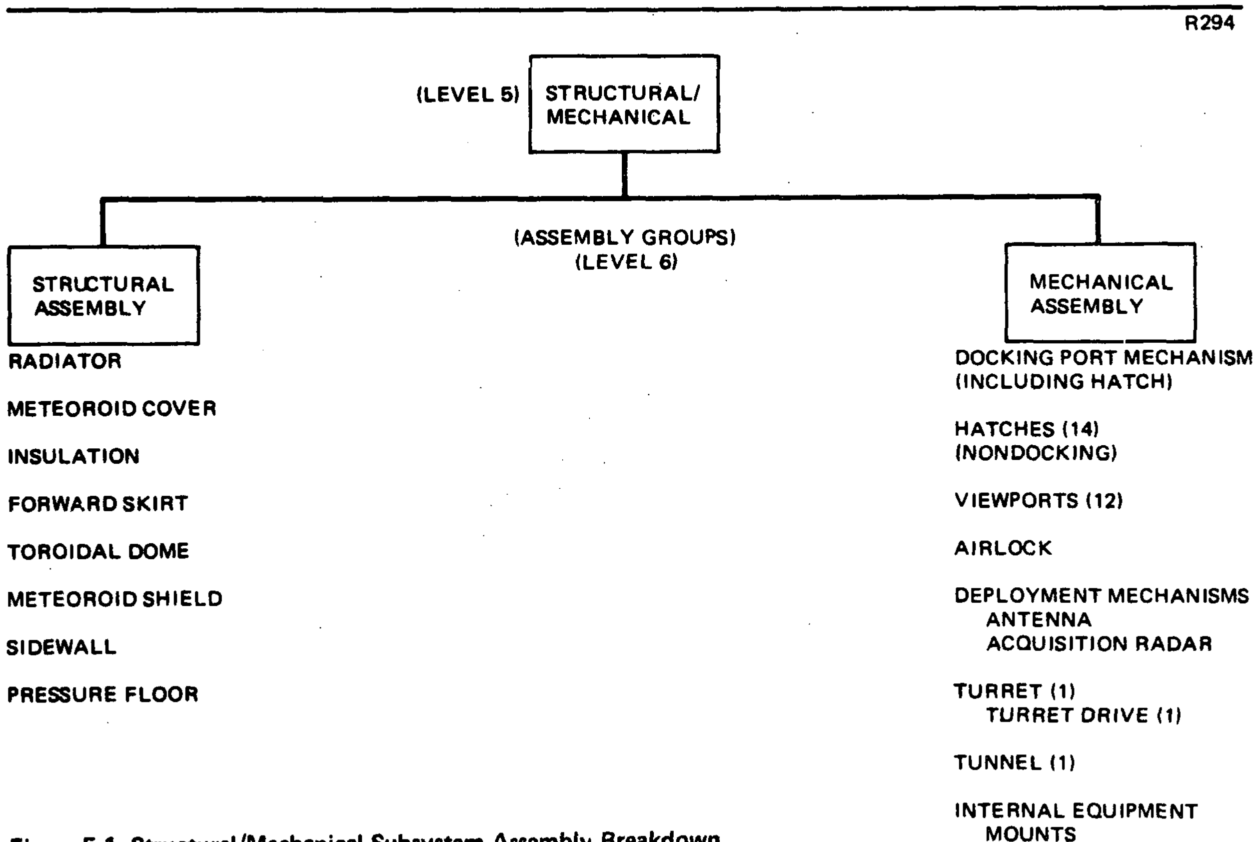


Figure 5-1. Structural/Mechanical Subsystem Assembly Breakdown

Definition

The task definition of this WBS box is contained in Appendix A.

Cost Assumptions, Ground Rules, and Rationale

There are none in addition to those in Section 2. 1. 2.

5. 1. 2 Costs

5. 1. 2. 1 Space Station Modules

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Cost Estimate

The total cost is estimated to be $76 million, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $58 million, begin 66 months prior to the milestone launch date of October 1980, and require 43 months for completion.

Production—It is estimated that the production effort will cost $18 million, will begin 43 months prior to the milestone launch date of October 1980, and will require 17 months for completion.

Operations—It is estimated that the operations effort will cost less than $0. 5 million, will begin 28 months prior to the milestone launch date of October 1980, and will continue for 28 months.

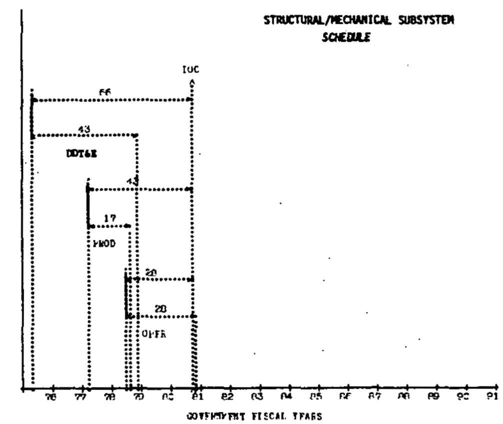
Funding Distribution

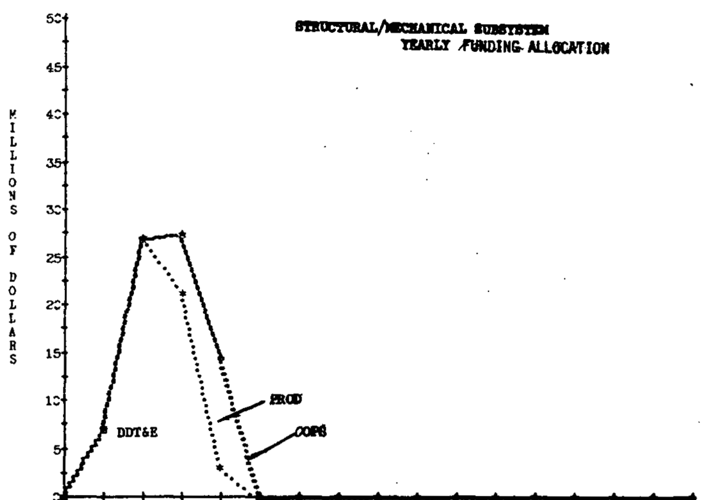
Figure 5-2 is a summary chart that highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government fiscal year (midyear plot). DDT&E funding has been spread, using a 60-percent spread function, production funding was spread at 40 percent, and operations funding is based on a composite spread function.

STRUCTURAL/MECHANICAL SUBSYSTEM	TECHNICAL DESCRIPTION	WBS 2275X02
MAJOR SUBASSEMBLY/GROUP	TOTAL WEIGHT (LB.)	CHARACTERISTICS
Structures		
Forward Skirt	1017	Milled Ribs - 3 Pieces - Breakformed and milled ring from forging
End Dome	134	Milled
Sidewall	6096	Milled Waffle - 3 Pieces - Welded
Pressure Floor	712	Aluminum Honeycomb Inside Plate
Hatches (14)	988	Honeycomb Dome
Viewports (12)	269	Machined and builtup
Tunnel	249	Isogrid - Milled
Turret	463	Machined forged hemispheres
Turret Drive	100	Electro-mechanical drive mechanism
Internal Equipment Mounts	800	"Bird Cage" - truss-like extrusions - longitudinals with cross members
Meteoroid/Thermal Protection		
Radiator	2959	Extrusions and Flat Plate
Insulation	1476	50 Layers - Double aluminized Mylar with Dacron Gauze
Meteoroid Cover	904	Double Sheet
Docking Provisions (12)	3359	Sidewall rings - builtup structure - hydraulics

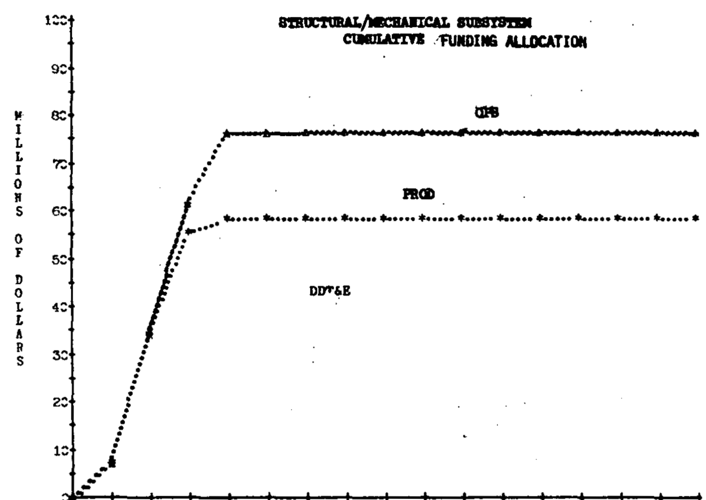
Additional Cost Considerations

Technology - Current	Commonality	Complexity
Working Pressure (15 PSIA)	Size	Workability
Ultimate Pressure (30 PSIA)	Material	Method of Fabrication
Shape	Multiple Usage	Growth
Quantity - Subassemblies/Components		





GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT•E	7•2	27•0	21•2	3•1	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
PROD	•0	•0	6•3	11•4	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
OPER	•0	•0	•0	•1	•2	•1	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
TOTAL	7•2	27•0	27•5	14•6	•2	•1	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT•E	7•2	34•2	55•4	58•5	58•5	58•5	58•5	58•5	58•5	58•5	58•5	58•5	58•5	58•5	58•5	58•5
PROD	•0	•0	6•3	17•7	17•7	17•7	17•7	17•7	17•7	17•7	17•7	17•7	17•7	17•7	17•7	17•7
OPER	•0	•0	•0	•1	•3	•4	•4	•4	•4	•4	•4	•4	•4	•4	•4	•4
TOTAL	7•2	34•2	61•7	76•3	76•5	76•6	76•6	76•6	76•6	76•6	76•6	76•6	76•6	76•6	76•6	76•6

Figure 5-2. Structural/Mechanical Subsystem Summary Chart

5.1.2.1.1 Power/Subsystems Module

The estimated cost of the structural and mechanical subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
29	7	0	37

5.1.2.1.2 Crew/Operations Module

The estimated cost of the structural and mechanical subsystem for this module is as follows

1972 Dollars in Millions

DDT&E	Production	Operations	Total
8	5	0	13

5.1.2.1.3 GPL Module

The schedule for the Space Station Modules structure and mechanical sub-module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
21	6	0	27

5.1.3 Schedule

The schedule for the Space Station Modules structure and mechanical subsystem is shown in Figure 5-3. This schedule identified equivalent subsystem-level equipment requirements (Table 5-3) and development activities required to design, test, and produce the subsystem. The schedule shows major milestones, key events, and critical actions related to the subsystem.

The structure and mechanical subsystem design engineering will start at Phase C/D ATP. The design requirements and design approach required for Preliminary Design Review (PDR) are established to meet the PDR date of October 1976. The engineering release (ER) for the structure and mechanical

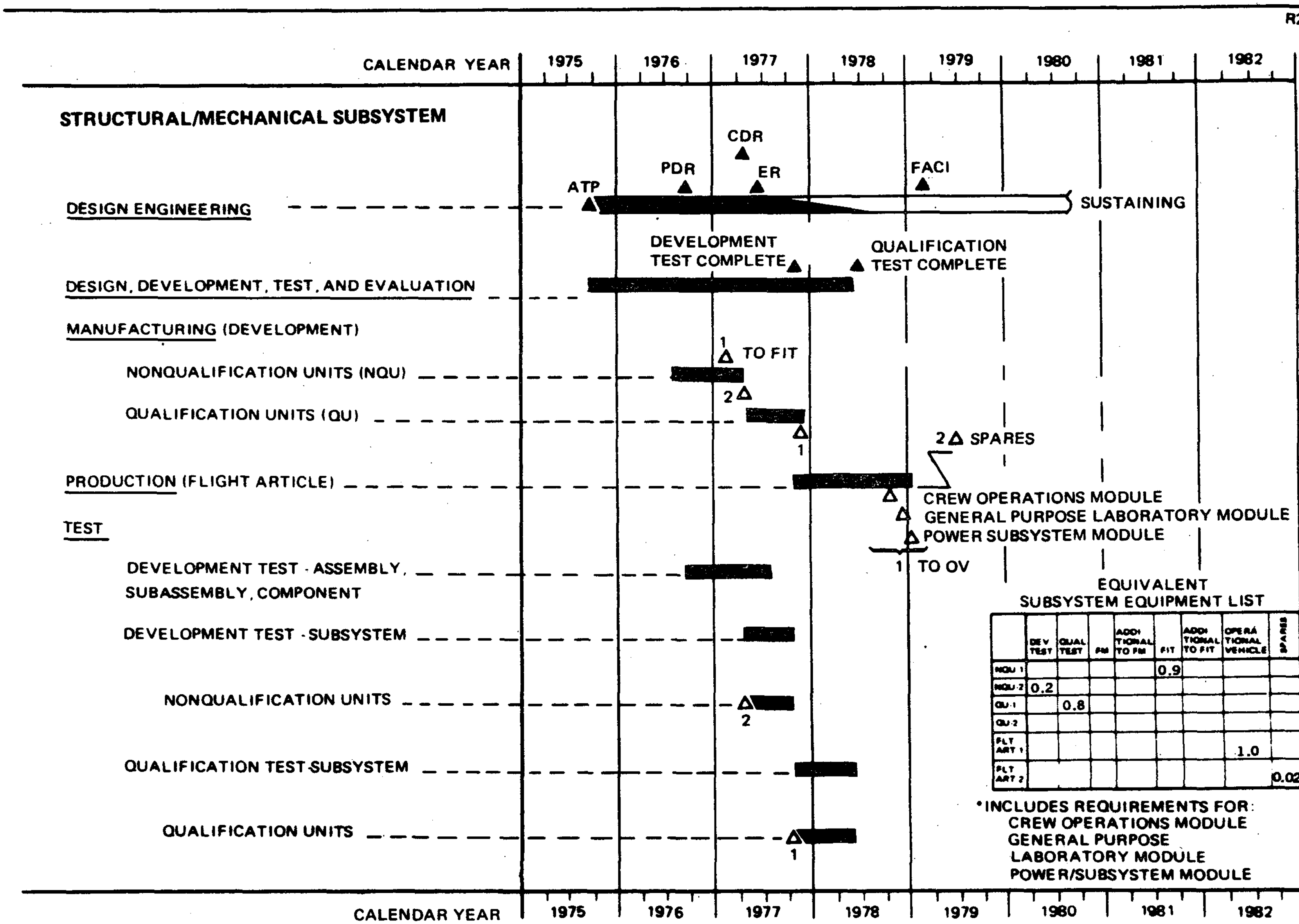


Figure 5-3. Structural/Mechanical Subsystem Schedule (ISS Only)

Table 5-3

STRUCTURE AND MECHANICAL EQUIVALENT SUBSYSTEM EQUIPMENT LIST LEGEND

	Development Test	Qualification Test	FM	Additional to FM	FIT	Additional to FIT	Operational Vehicle	Spares
NQU-1					0.9			
NQU-2	0.2							
QU-1		0.8						
FA-1							1.0	
FA-2								0.025

subsystem occurs 21 months after Phase C/D ATP and 9 months prior to the final Space Station Modules system ER data. The Critical Design Review (CDR) occurs 2 months before the ER. The First Article Configuration Inspection (FACI) is performed at the time of delivery of the flight hardware in February 1979. The DDT&E begins with Phase C/D ATP and ends at qualification test completion in October 1978.

The manufacturing time span begins with the nonqualification units in October 1976 and ends when manufacturing of the production units for spares is completed in July 1979.

Two nonqualification units are produced, and one is shipped directly to the FIT upon completion of manufacture. The second nonqualification unit (0.2 equivalent) is used for a 6-month period in development testing of the subsystem. One qualification unit is produced for the qualification testing of 8-month duration. Additional testing is performed early in the development phase at the component, subassembly, and assembly levels.

There are two areas of technical capability in the structural and mechanical subsystem that are unique and will require special attention during the design and development period: structural analysis through computer redundant-force analysis programs and mass properties management. The FORTRAN

Matrix Abstraction Technique (FORMAT) is a FORTRAN computer program designed for direct and simple implementation of the extensive structural technology published in matrix notation. Matrices up to 2,000 order can be accommodated in the basic FORMAT system; and a special version of the displacement method, MINI-FORMAT, can solve statics problems up to 4,000 order. The SA-49 (modified FORMAT III) computer program will be applied to provide a highly automated system for analysis of large complex structures, using the force or displacement method (finite element analysis). The internal forces and deflections, critical loads and buckling modes, and resonant frequencies and vibration modes will be determined, using the SA-49 program. The loading can be mechanical or thermal, and both force and displacement methods are fully implemented.

Mass properties management for the Space Station will be more complex and critical than previous programs to insure the fulfillment of the program objectives and contractual requirements. This criticality is associated with the size of the Space Station, mission life, experiment program, and mass-balance associated with the continuing logistics resupply.

The existing computer programs provide the weight analyst with an automatic data processing capability to record and report mass properties from the first stages of planning and development to the conclusion of the program.

The environmental criteria and design constraints require investigations and special emphasis in three areas: dynamic seals, lubrication, and the structurally integrated meteoroid shield-radiator-insulation concept. Dynamic seals will be used to prevent or restrict loss of a gas or liquid across and interface subject to translation or rotation. Designs incorporating rotating seals with the large diameters projected for the Space Station program are not presently in production; performance data are therefore not available. A development test program to investigate details of seal design and type of materials to use, along with persistent attention to detail, is required to provide seals with high reliability and long life.

An investigation of lubricants and accelerated life, testing in a simulated space environment, is necessary to assure high reliability and long life for operating mechanisms and components.

The search for efficient structural configurations has led to an integrated structural concept of a meteoroid shield-radiator-insulation system. The complex design and functional requirements between the three systems will require a systems design approach, with special attention given to detail throughout the design phase to assure that the resulting concept is an optimum design.

5.2 ELECTRICAL POWER SUBSYSTEM (WBS 2 x 75 x 24)

5.2.1 Summary

The electrical power subsystem includes a solar array power source, deployment and orientation mechanisms, energy management equipment, storage and regulation equipment, power conditioning equipment, and power distribution protection and switching assemblies.

This subsystem is illustrated in the WBS assembly level breakdown in Figure 5-4.

Definition

The task definition of this WBS box is contained in Appendix A.

Cost Assumptions, Ground Rules, and Rationale

There are none in addition to those in Section 2.1.2.

5.2.2 Costs

5.2.2.1 Space Station Modules

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Cost Estimate

The total cost is estimated to be $157 million, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $94 million, will begin 66 months prior to the milestone launch date of October 1980, and will require 57 months for completion.

Production—It is estimated that the production effort will cost $29 million, will begin 38 months prior to the milestone launch date of October 1980, and will require 22 months for completion.

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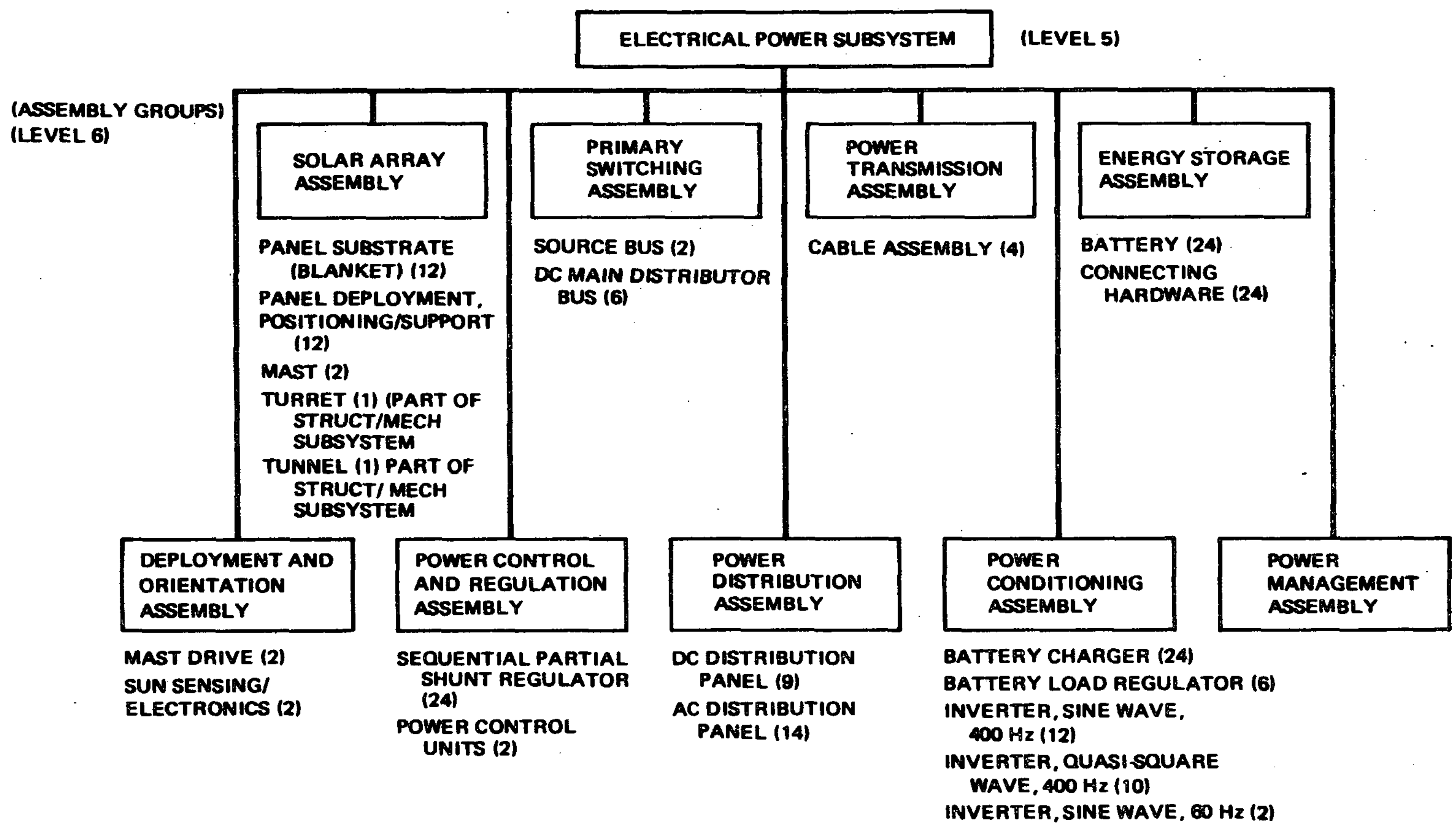


Figure 5-4. Electrical Power Subsystem Assembly Group Breakdown

Operations—It is estimated that the operations effort will cost $34 million, will begin 18 months prior to the milestone launch date of October 1980, and will continue for 19 months.

Funding Distribution

Figure 5-5 is a summary chart that highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government fiscal year (midyear plot). DDT&E funding has been spread, using a 60-percent spread function, production funding was spread at 40 percent, and operations funding is based on a composite spread function.

5.2.2.1.1 Power/Subsystems Module

The estimated cost of the electrical power subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
84	23	28	135

5.2.2.1.2 Crew/Operations Module

The estimated cost of the electrical power subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
5	3	3	11

5.2.2.1.3 GPL Module

The estimated cost of the electrical power subsystem for this module is as follows:

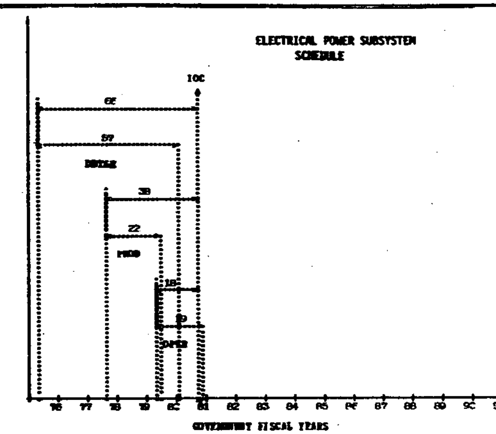
1972 Dollars in Millions

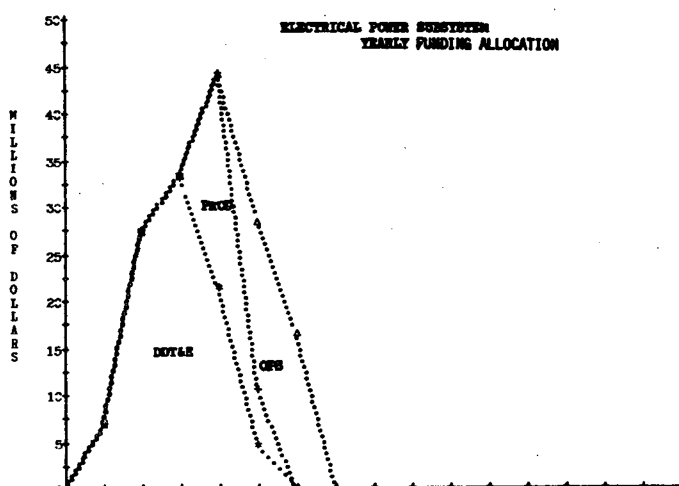
DDT&E	Production	Operations	Total
5	3	3	11

ELECTRICAL POWER SUBSYSTEM	TECHNICAL DESCRIPTION	WBS 2X75X24
MAJOR SUBASSEMBLY/GROUP	TOTAL WEIGHT (LB.)	CHARACTERISTICS
Solar Array(Incl. Array, Astromast Stowage and Deployment, Tracking and Transfer)	2967	5300 Ft.^{2} Array; 17.3 KWe; Gimballed foldout arrays; Lockheed LMSC Design - Astromast
Controls	338	
Conditioning	610	
Transmission	600	115 VDC ; Sequential Partial Shunt Regulator
Distribution	2402	
Switching and Cabling	680	
Batteries (24)	9120	100 Amp-Hour; Nickel Cadmium

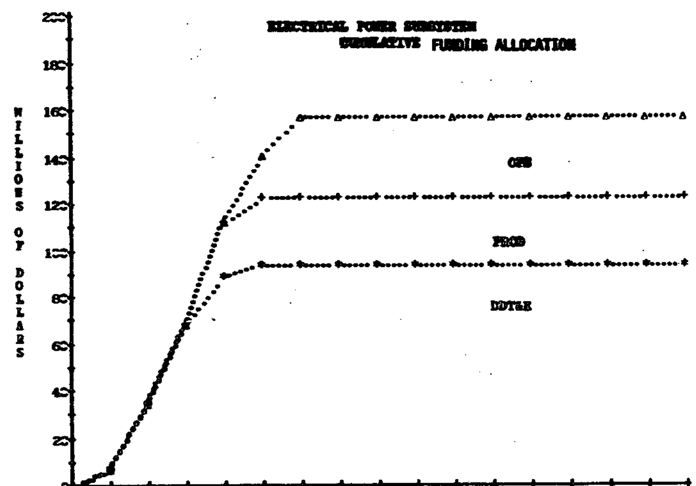
Additional Cost Considerations

- Technology - Generally Current, with some Technology Development of Solar Array required
- Rated Output
- Size/Shape/Material
- Method of Fabrication
- Commonality
- Complexity
- Multiple Usage
- Quantity - Subassemblies/Components





GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT•E	7•1	27•6	33•1	21•5	4•7	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
PROD	•0	•0	•4	22•7	6•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
OPER	•0	•0	•0	•0	17•8	16•8	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
TOTAL	7•1	27•6	33•5	44•2	28•5	16•8	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT•E	7	34	67	89	93	93	93	93	93	93	93	93	93	93	93	93
PROD	0	0	0	23	29	29	29	29	29	29	29	29	29	29	29	29
OPER	0	0	0	0	17	34	34	34	34	34	34	34	34	34	34	34
TOTAL	7	34	68	112	140	157	157	157	157	157	157	157	157	157	157	157

Figure 5-5. Electrical Power Subsystem Summary Chart

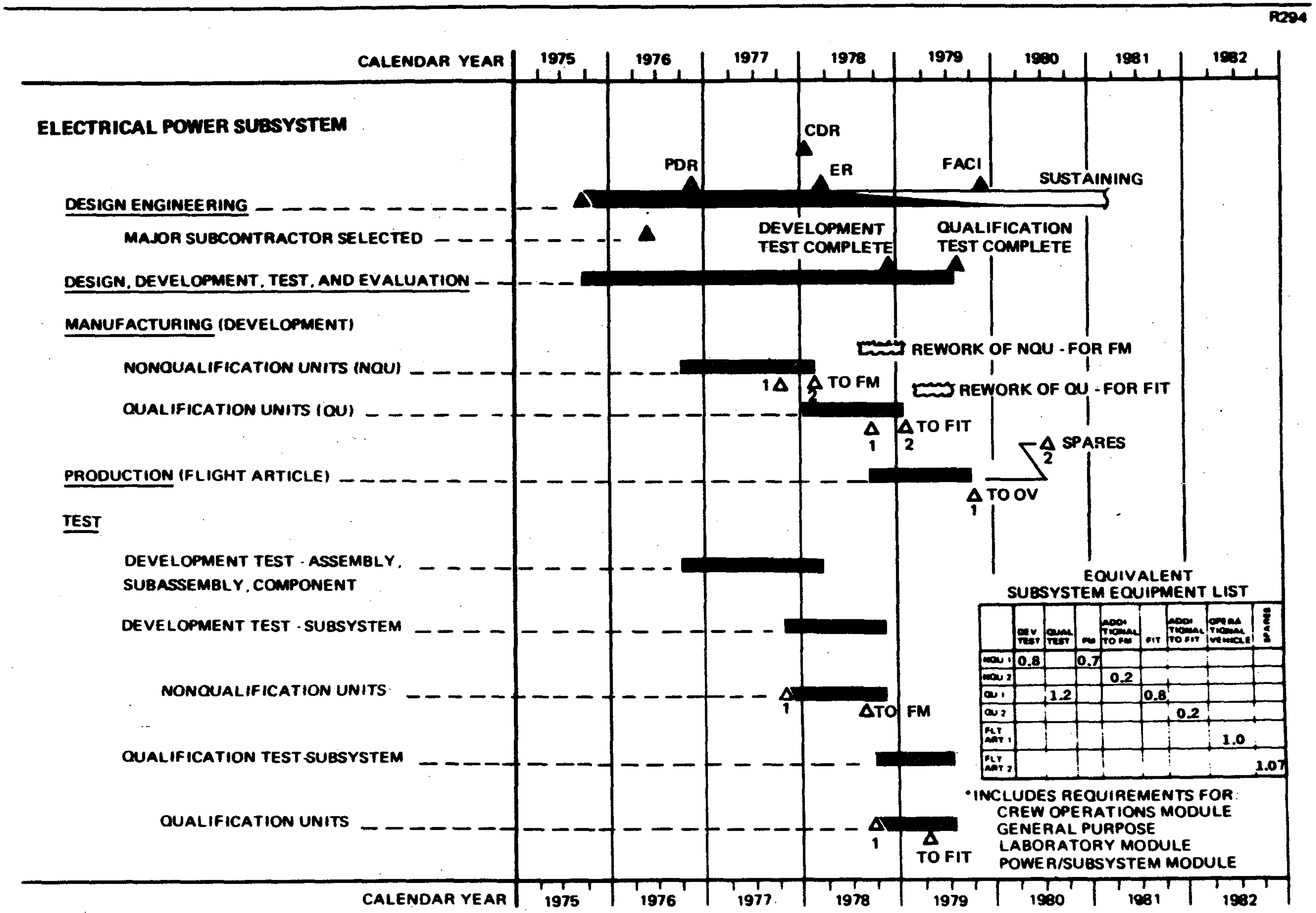
5.2.3 Schedule

The schedule for the Space Station Modules electrical power subsystem is shown in Figure 5-6. This schedule identifies equivalent subsystem-level equipment requirements (Table 5-4) and development activities required to design, test, and produce the subsystem. The schedule provides major milestones, key events, and critical actions related to the subsystem.

The electrical power subsystem design engineering starts at Phase C/D ATP. Major subcontractor ATP occurs 8 months into Phase C/D to establish the design requirements and design approach required for Preliminary Design Review (PDR). The engineering release (ER) for the electrical power subsystem occurs 30 months after Phase C/D ATP and is coincident with the Space Station Modules system ER final date. The Critical Design Review (CDR) occurs 2 months before ER. The First Article Configuration Inspection (FACI) is performed at the time of delivery of the flight hardware in November 1979. The DDT&E begins with Phase C/D design and ends at qualification test completion in October 1979.

The manufacturing time span begins with the nonqualification units in October 1976 and is completed with the manufacturing of the production units for spares in August 1980.

One nonqualification unit is produced and used in development testing of the subsystem. Three months before the completion of the test, 50 percent of the unit is shipped to the functional model. A second nonqualification unit is shipped directly to the FM upon completion of manufacture. One qualification unit is produced for the qualification testing. Three months before completion of the qualification test, 60 percent of the unit is shipped to the flight integration tool for integration and testing. A second qualification unit is shipped directly to the FIT upon completion of manufacture. Additional testing is performed early in the development phase at the component, subassembly, and assembly levels.



	DEV TEST	QUAL TEST	FM	ADDITIONAL TO FM	FIT	ADDITIONAL TO FIT	OPERATIONAL VEHICLE	SPARES
NQU 1	0.8		0.7					
NQU 2				0.2				
QU 1		1.2			0.8			
QU 2						0.2		
FLT ART 1							1.0	
FLT ART 2								1.0*

Figure 5-6. Electrical Power Subsystem Schedule (ISS Only)

Table 5-4

ELECTRIC POWER EQUIVALENT SUBSYSTEM EQUIPMENT LIST LEGEND

	Development Test	Qualification Test	FM	Additional to FM	Fit	Additional to FIT	Operational Vehicle	Spares
NQU-1	0.8		0.7					
NQU-2				0.2				
QU-1		1.2			0.8			
QU-2						0.2		
FA-1							1.0	
FA-2								1.07

The EPS will require unique design, development, and test activities, primarily in the elements of the solar array and deployment and orientation assemblies. The array system utilizes two solar array wings for a total of 492 m^2 (5,300 sq ft) in area. Each wing is composed of two contained packages of flat-folded flexible substrate array blankets and one truss structure extendible mast (an Astro-mast). Each package contains a quadrant of the two-wing array. The mast is deployed between the two array blanket packages. The tops of the blanket packages act as a tee across the outboard end of the boom and pull the array blankets outward during mast deployment. The two canisters containing the deployable booms for the two array wings are attached to either side of a central turret, which contains the wing tracking drives and the array power-transfer assemblies. By rotating the deployment booms about their longitudinal axis of the power module, 360 degrees, two-axes tracking of the two array wings is accomplished. The solar array panels, orientation drive, and power transfer systems are defined as the major problem areas, and they will require extensive investigation, development, and qualification.

Many of the components and assemblies used in the other assembly groups have been employed in other programs and are categorized as standard equipment design. However, difficulties relating to development of energy storage, power regulation and control, and power management will require detail attention and development verification to assure all technical characteristics are achieved.

5.3 ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM (WBS 2 x 75 x 05)

5.3.1 Summary

The EC/LS subsystem includes the equipment that provides:

- Atmosphere supply and control
- Atmosphere regeneration
- Atmosphere purification
- Water management
- Waste management
- IVA/EVA equipment
- Thermal control

This subsystem is illustrated in the WBS assembly level breakdown in Figure 5-7.

Definition

The task definition of this WBS box is contained in Appendix A.

Cost Assumptions, Ground Rules, and Rationale

There are none in addition to those in Section 2.1.2.

5.3.2 Costs

5.3.2.1 Space Station Modules

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

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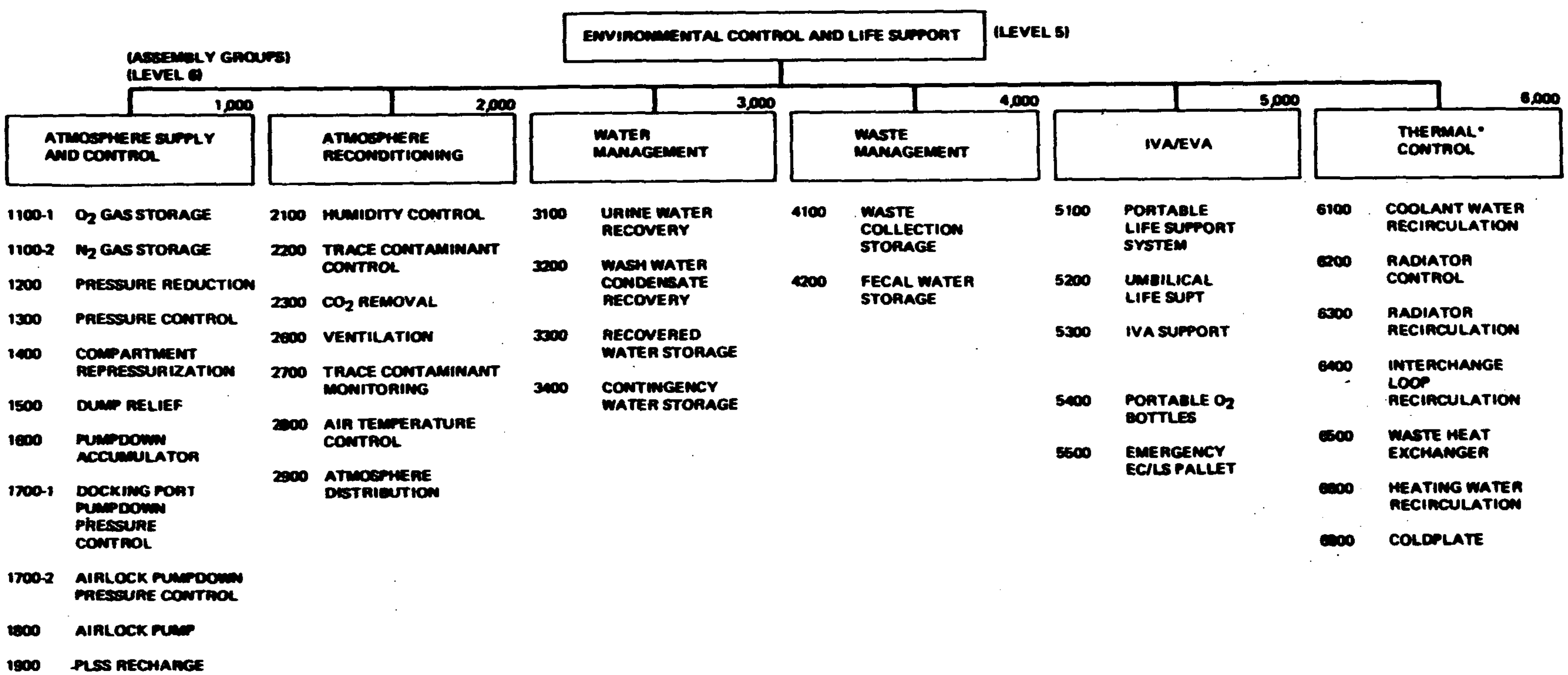


*RADIATOR AND INSULATION ARE PART OF STRUCTURE

Figure 5-7. EC/LS Subsystem Assembly Group Breakdown

Cost Estimate

The total cost is estimated to be $144 million, as follows:

DDT&E – It is estimated that the DDT&E effort will cost $94 million, will begin 66 months prior to the milestone launch date of October 1980, and will require 52 months for completion.

Production – It is estimated that the production effort will cost $20 million, will begin 37 months prior to the milestone launch date of October 1980, and will require 17 months for completion.

Operations – It is estimated that the operations effort will cost $30 million, will begin 23 months prior to the milestone launch date of October 1980, and will continue for 12 months.

Funding Distribution

Figure 5-8 is a summary chart that highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government fiscal year (midyear plot). DDT&E funding has been spread, using a 60 - percent spread function, production funding was spread at 40 percent, and operations funding is based on a composite spread function.

5.3.2.1.1 Power/Subsystems Module

The estimated cost of the environmental control and life support subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
29	7	10	47

5.3.2.1.2 Crew/Operations Module

The estimated cost of the environmental control and life support subsystem for this module is as follows:

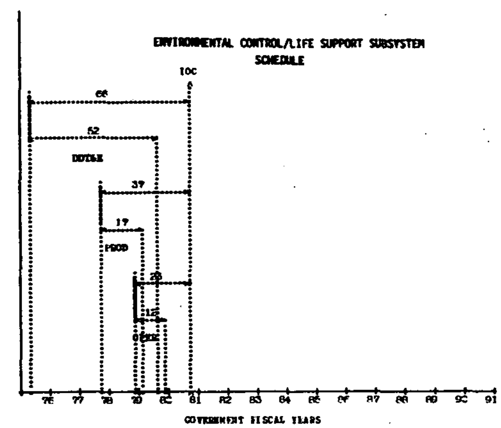
1972 Dollars in Millions

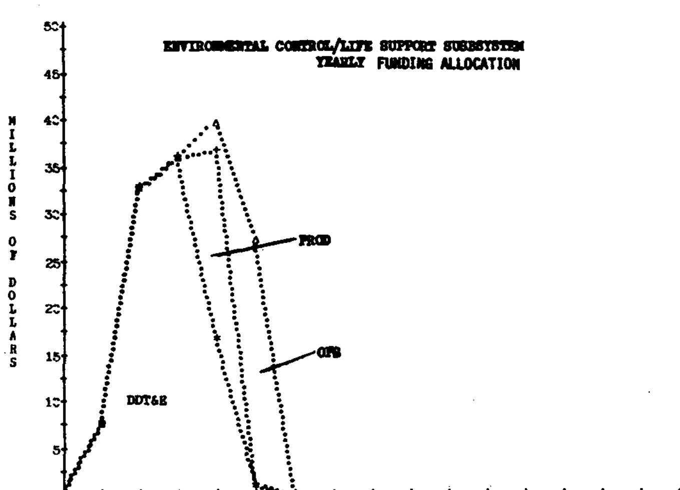
DDT&E	Production	Operations	Total
41	7	10	58

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM	TECHNICAL DESCRIPTION				WBS 2X75X05
MAJOR SUBASSEMBLY/GROUP	NO. EQUIV. UNITS	TOTAL WEIGHT (LB.)	AVE. POWER (WATTS)	VOLUME (CU.FT.)	CHARACTERISTICS
Atmosphere Supply and Control	4	2660	20	138	
Atmosphere Reconditioning	2	1692	304	138	
Water Management	1	1548	64	119	
Waste Management	2	132	0	9	
IVA/EVA	4	1716	0	70	
Thermal Control	3	742	0	20	(Solar Collector on Solar Arrays)
TOTALS	2	8490	388	494	

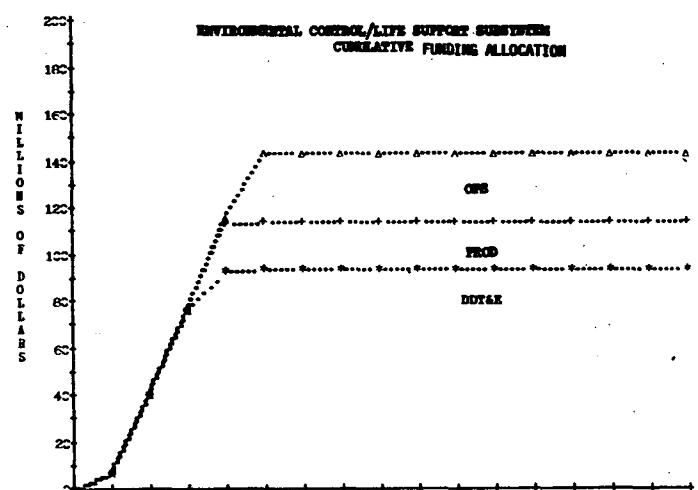
Additional Cost Considerations

Two - 6-Man Systems	Commonality
Closed Water	Complexity
Open Oxygen	Safety
Size/Material/Fabrication Method	Multiple Usage
Volume - Pressure Vessels	Growth
Quantity - Subassemblies/Components	Similarity to Existing Units
Operating Pressure	
Technology - Current	





GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT•E	7•7	32•8	35•9	16•8	1•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
PROD	•0	•0	•2	20•0	•2	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
OPER	•0	•0	•0	2•9	26•2	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
TOTAL	7•7	32•8	36•1	39•7	27•4	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT•E	7	40	76	93	94	94	94	94	94	94	94	94	94	94	94	94
PROD	0	0	0	20	20	20	20	20	20	20	20	20	20	20	20	20
OPER	0	0	0	2	29	29	29	29	29	29	29	29	29	29	29	29
TOTAL	7	40	76	116	143	143	143	143	143	143	143	143	143	143	143	143

Figure 5-8. Environmental Control and Life Support Subsystem Summary Chart

5.3.2.1.3 GPL Module

The estimated cost of the environmental control and life support subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
24	6	10	39

5.3.3 Schedule

The EC/LS subsystem design engineering starts at Phase C/D ATP. (See Table 5-5 and Figure 5-9.) Major subcontractor ATP occurs 10 months into Phase C/D to establish the design requirements and design approach required for Preliminary Design Review (PDR). It will be necessary to select assembly-level subcontractors early in Phase C/D to allow them sufficient time to complete their development and to meet the schedule requirements. Before the major subcontractor receives ATP, such activities such as specification release, request for bids, proposal preparation, and evaluation must be completed.

The engineering release (ER) for the EC/LS subsystem occurs 25 months after Phase C/D ATP and 5 months before the Space Station Modules system ER final date. The Critical Design Review (CDR) occurs 2 months before ER. The First Article Configuration Inspection (FACI) is performed at the time of delivery of the flight hardware in October 1979. The DDT&E begins with Phase C/D ATP and ends at qualification test completion in April 1979.

Table 5-5

ENVIRONMENTAL CONTROL AND LIFE SUPPORT EQUIVALENT SUBSYSTEM EQUIPMENT LIST LEGEND

	Development Test	Qualification Test	FM	Additional to FM	FIT	Additional to FIT	Operational Vehicle	Spares
NQU-1	0.5		0.2					
QU-1		0.4			1.0			
QU-2						0.8		
FA-1							1.0	
FA-2								2.06

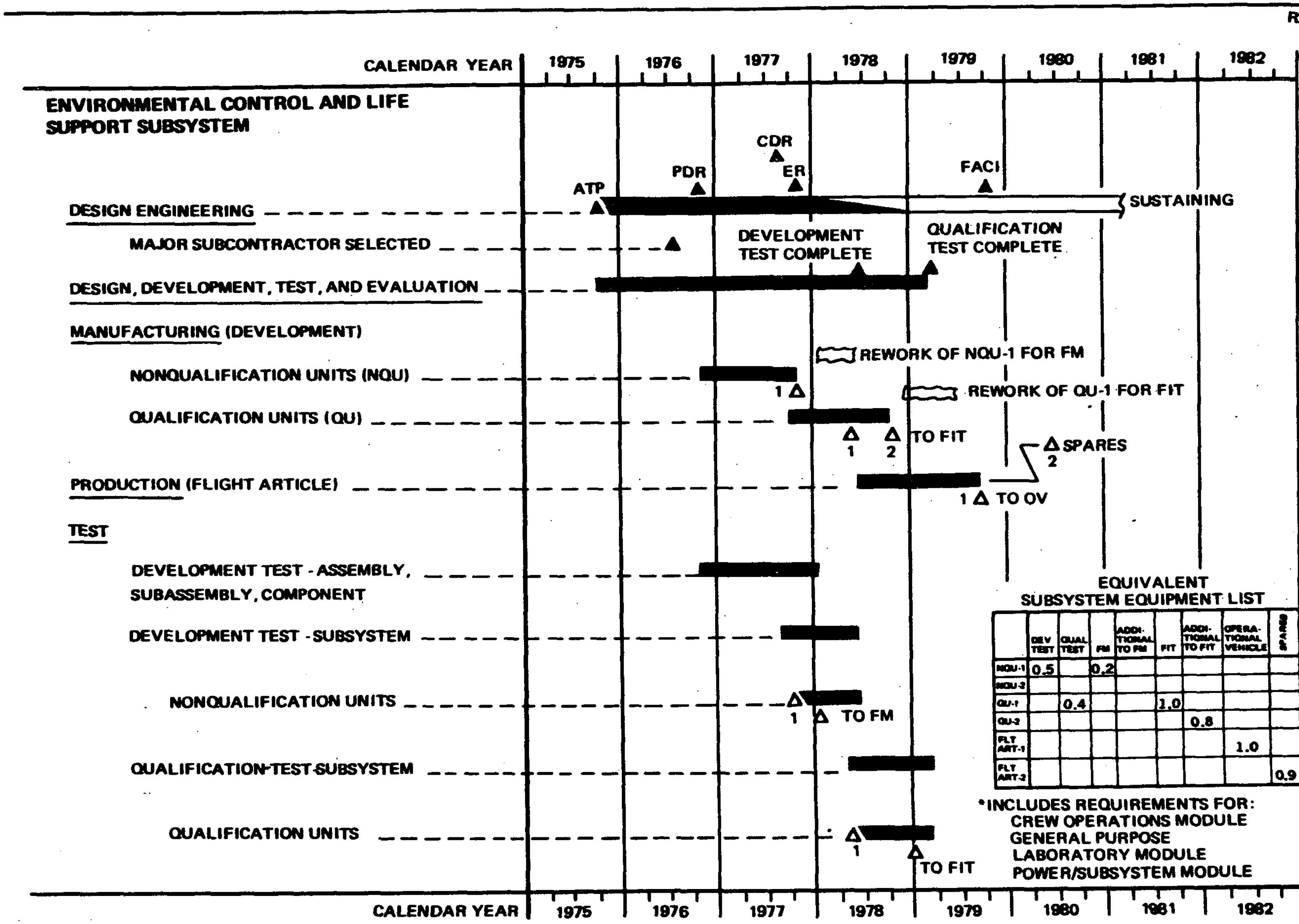


Figure 5-9. Environmental Control and Life Support Subsystem Schedule (ISS Only)

The manufacturing time span begins with the nonqualification units in September 1976 and is completed with manufacture of the production units for spares in June 1980.

One nonqualification unit is produced and used in development testing (9-month duration) of the subsystem. At the end of 3 months, approximately 20 percent of the unit is shipped to the functional model (FM). One qualification unit is produced for the qualification testing (11-month duration). Three months before the completion of the qualification test, 20 percent of the unit is shipped to the flight integration tool (FIT) for integration and testing. A second qualification unit is shipped directly to the FIT upon completion of manufacture. Additional testing is performed early in the development phase at the component, subassembly, and assembly levels.

The EC/LS subsystem is composed of many different assemblies that require integration with each other and with the configuration. A diversity of technology is required to develop a successful subsystem, including high-pressure gas storage, atmosphere pressure and composition control, vacuum pumping, conventional atmosphere temperature and humidity control, atmosphere CO_2 control via adsorptive beds, membrane electrochemistry, urine and wash water purification, and fluid-heat transport circuits.

The key problems at the assembly level are the development of the urine, wash water, and condensate water recovery assemblies. These represent the most difficult development problems, and SRT funding is required. The depth of funding and the success achieved in the SRT development will affect the magnitude of the development problem in Phase C/D.

The key subsystem-level problems are (1) the integration of the many assemblies so that they are compatible with each other and (2) the integration of these assemblies into the configuration. Many of these assemblies, such as atmosphere temperature control, atmosphere ventilation, and the heat-transport circuits, are sensitive to the configuration. Therefore, it is vital to complete an integrated EC/LS subsystem-level test with a simulated installation before final qualification of the assemblies.

5.4 PROPULSION/REACTION CONTROL SUBSYSTEM (WBS 2 x 75 x 23)

5.4.1 Summary

This subsystem provides the thrust impulse required to maneuver and position the Space Station in orbit. Station P/RCS is comprised of a high-thrust bipropellant system and a low-thrust resistojet system. The high-thrust system provides the final orbit adjustment, maneuvers, scheduled disturbances and backup attitude control. The low thrust system will provide the orbit keeping and CMG desaturation functions.

This subsystem is illustrated in the WBS assembly level breakdown in Figure 5-10.

Definition

The task definition of this WBS box is contained in Appendix A.

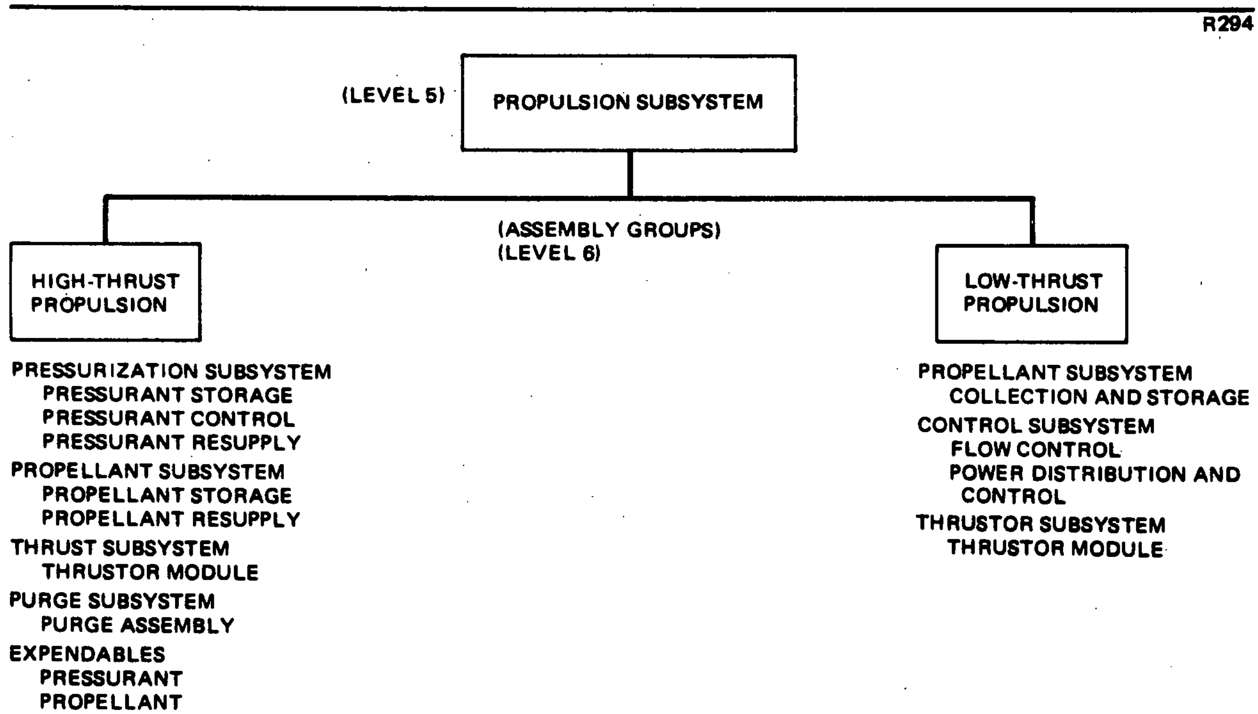


Figure 5-10. Propulsion Subsystem Assembly Breakdown

Cost Assumption, Ground Rules and Rationale

There are none in addition to those in Section 2.1.2.

5.4.2 Costs

5.4.2.1 Space Station Modules

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Cost Estimate

The Total Cost is estimated to be $35 million, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $19 million, will begin 66 months prior to the milestone launch date of October 1980, and will require 48 months for completion.

Production—It is estimated that the production effort will cost $8 million, will begin 36 months prior to the milestone launch date of October 1980, and will require 13 months for completion.

Operations—It is estimated that the operation effort will cost $8 million, will begin 25 months prior to the milestone launch date of October 1980, and will continue for 13 months.

Funding Distribution

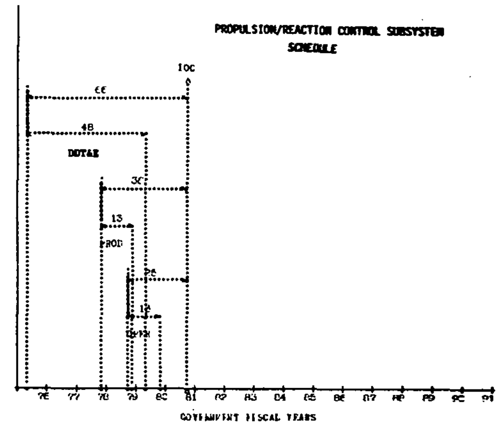
Figure 5-11 is a summary chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government fiscal year (midyear plot). DDT&E funding has been spread using a 60 percent spread function, while production funding was spread at 40 percent, and operations funding is based on a composite spread function.

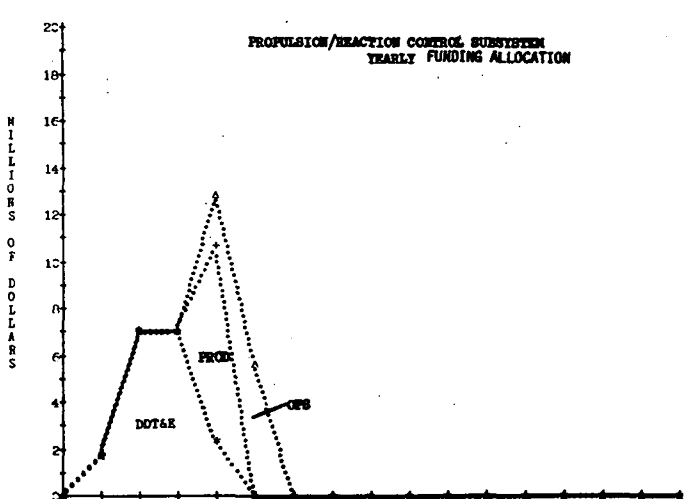
PROPULSION/REACTION CONTROL SUBSYSTEM — TECHNICAL DESCRIPTION — WBS 2X75X23

MAJOR SUBASSEMBLY/GROUP	NO. OF FLIGHT UNITS	TOTAL WEIGHT (LB.)	CHARACTERISTICS
High Thrust		(2136)	(Dry) - Monopropellant Hydrazine (N_2H_4)
Propellant Storage	4	440	18-in.Dia X 45-in Long Cylindrical Tanks - 300 PSIA
Pressurization Storage	2	239	19.5-in.Dia. Spheres - 3000 PSIA - Titanium
Purge Storage	2	81	1-Ft.^{3} - Spheres - 3000 PSIA - Titanium
Thrustors	40	312	25-LBF Thrust;
Plumbing, Valves	1	335	
Support Structure	1	231	
Low Thrust		(403)	(Dry) - CO_2 Resistojets
Propellant			Biowaste Gases - CO_2
Thrustors	32		0.02-LBF Thrust; ISP 175 Sec.

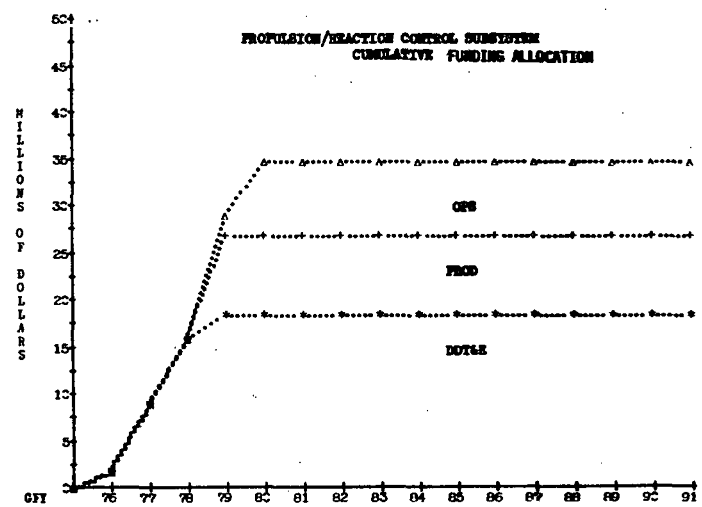
Additional Cost Considerations

Technology - Current	Commonality
Size/Material/Shape	Method of Fabrication
Volume - Pressure Vessel	Quantity - Subassemblies/Components
Complexity	Similarity to Existing Units
Safety	Growth





GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT·E	1·8	7·1	7·0	2·4	·0	·0	·0	·0	·0	·0	·0	·0	·0	·0	·0	·0
PROD	·0	·0	·1	8·3	·0	·0	·0	·0	·0	·0	·0	·0	·0	·0	·0	·0
OPER	·0	·0	·0	2·2	5·7	·0	·0	·0	·0	·0	·0	·0	·0	·0	·0	·0
TOTAL	1·8	7·1	7·1	12·9	5·7	·0	·0	·0	·0	·0	·0	·0	·0	·0	·0	·0



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT·E	1·8	8·9	15·9	18·3	18·3	18·3	18·3	18·3	18·3	18·3	18·3	18·3	18·3	18·3	18·3	18·3
PROD	·0	·0	·1	8·4	8·4	8·4	8·4	8·4	8·4	8·4	8·4	8·4	8·4	8·4	8·4	8·4
OPER	·0	·0	·0	2·2	7·9	7·9	7·9	7·9	7·9	7·9	7·9	7·9	7·9	7·9	7·9	7·9
TOTAL	1·8	8·9	16·0	28·9	34·6	34·6	34·6	34·6	34·6	34·6	34·6	34·6	34·6	34·6	34·6	34·6

Figure 5-11. Propulsion/Reaction Control Subsystem Summary Chart

5.4.2.1.1 Power/Subsystems Module

The estimated cost of the propulsion/reaction control subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
8	3	3	14

5.4.2.1.2 Crew/Operations Module

The estimated cost of the propulsion/reaction control subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
11	5	5	21

5.4.2.1.3 GPL Module

The estimated cost of the propulsion/reaction control subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
0	0	0	0

5.4.3 Schedule

The schedule for the Space Station Modules propulsion subsystem is shown in Figure 5-12. This schedule identifies equivalent subsystem level equipment requirements (Table 5-6) and development activities required to design, test, and produce the subsystem.

The propulsion design engineering will start at Phase C/D ATP. Major subcontractor ATP occurs 8 months into the Phase C/D to establish the design requirements and design approach required for Preliminary Design Review (PDR). Specification control drawings must be prepared, approved, and submitted for bid to allow for early selection of vendor. The engineering release (ER) for the propulsion subsystem occurs 24 months after Phase C/D ATP and 6 months prior to the final Space Station Modules system ER date. The Critical Design Review (CDR) occurs two months before ER.

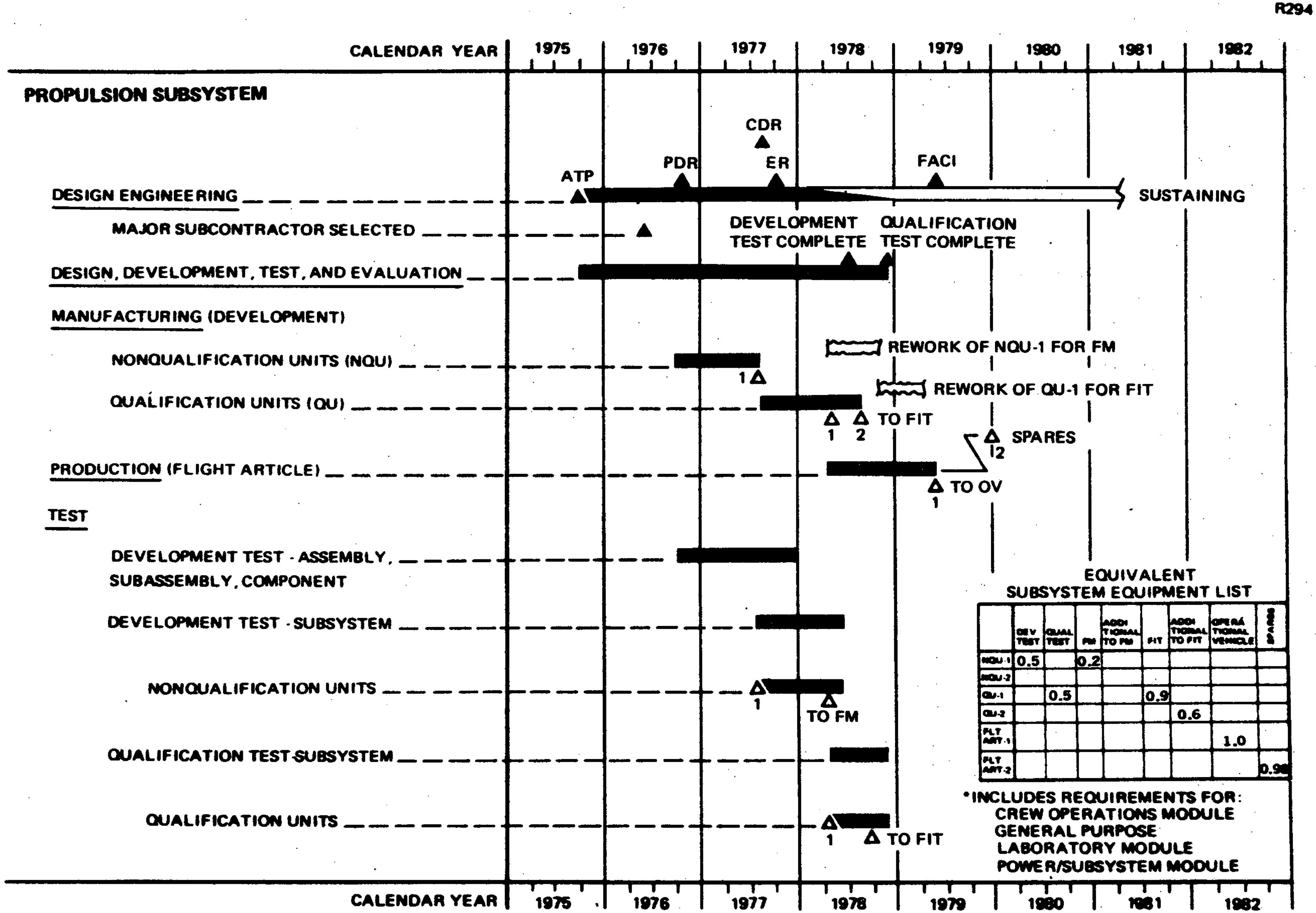


Figure 5-12. Propulsion Subsystem Schedule (ISS Only)

Table 5-6

PROPULSION/REACTION CONTROL EQUIVALENT SUBSYSTEM EQUIPMENT LIST LEGEND

	Development Test	Qualification Test	FM	Additional to FM	FIT	Additional to FIT	Operational Vehicle	Spares
NQU-1	0.5		0.2					
QU-1		0.5			0.9			
QU-2						0.6		
FA-1							1.0	
FA-2								0.985

The First Article Configuration Inspection (FACI) is performed at the time of delivery of the flight hardware in June 1979. The DDT&E begins with Phase C/D design and ends at qualification test completion in December 1978.

The manufacturing time span begins with the nonqualification units in October 1976 and is completed with the manufacture of the qualification units for spares in January 1980.

One nonqualification unit is produced and used in development testing (13-months duration) of the subsystem. Three months before completion of the test on the first unit, 20 percent of it is shipped to the functional model. One qualification unit is produced for the qualification testing (9-months duration). Two months before completion of the qualification tests, 30 percent of the unit is shipped to the flight integration tool for integration and testing. A second qualification unit is shipped to the FIT upon completion of manufacture. Additional testing is performed early in the development phase at the component, subassembly, and assembly levels.

The Space Station requirements for a 10-year operational life with maintainable subsystems pose some new and severe requirements on the propulsion subsystem. In particular, contamination of external surfaces with exhaust products must be minimized and maintenance provisions for toxic propellant assemblies and externally-mounted thrustors must be developed. Present ground decontamination and purging procedures have wasted consumables and have depended to a large degree upon atmospheric dilution to reduce toxicity. Careful preplanning of the procedure investigation must precede the design phase; strict attention to design detail will be required to provide a workable maintenance activity.

The integration of the low-thrust (CO_2 biowaste resistojet) with the EC/LS subsystem molecular series is a new concept; therefore, the control mode analysis, consumption schedule, and intersystem response characteristics must be studied in detail. The mechanical design of the subsystem, other than thrustors, is straightforward. The necessary thrustor design and development effort will be provided by SRT activity. Results of the SRT programs will be used as soon as available to update subsystem design.

The high-thrust (N_2H_4) assembly design is largely within the present state of the art. Special emphasis must be placed upon surface contamination and thrustor life. Both of these areas have been noted in the SRT requirements. Wherever possible, items previously developed for similar applications will be selected. The thrustor development for both the high- and low-thrust assemblies will be major subcontracts.

The propulsion subsystem development tests will be performed on both subsystem and assembly levels. For example, test firings of thrustor modules under simulated altitude conditions will be required to verify adequate protection against heat soak back, thermal effects on adjacent structure, and exhaust contamination. Subsystem level nonfiring thermal vacuum tests will be required to verify heater adequacy and electrical loads.

The high-thrust system development tests will consist of a complete subsystem installation which will be hot-fired after preliminary checkout for a series of duty cycles. The testing will include procedure development tasks to ensure that loading, resupply, decontamination, and repair can be performed on-orbit with a minimum crew involvement. The subsystem tests anticipated can readily be conducted at the Sacramento Test Center Gamma facility. Vacuum testing of the complete subsystem is not anticipated.

The low-thrust system development tests will be similar to those discussed for the high-thrust. If practical, integration with the EC/LS subsystem is desirable; however, the worth of such testing can only be determined after future SRT exploration in this area has been completed. The small thrustors and safer propellants can possibly allow testing to be done in a factory rather than a test area.

Most qualification testing will be conducted at the component level with combined environments. Subsystem qualification testing will use the development test setup, with updated components. Imposed environments will be minimized as far as practical in favor of severe component testing.

5.5 GUIDANCE AND NAVIGATION SUBSYSTEM (WBS 2 x 75 x 46)

5.5.1 Summary

The guidance and navigation (G/N) subsystem provides station navigational information to be used by experiments, logistics vehicles, experiment modules, etc. and generates guidance commands for orbit keeping and maneuvers. The G/N equipment consists of position and velocity sensors, electronics for sensors and computer interfaces, and display and control elements.

This subsystem is illustrated in the WBS assembly level breakdown in Figure 5-13.

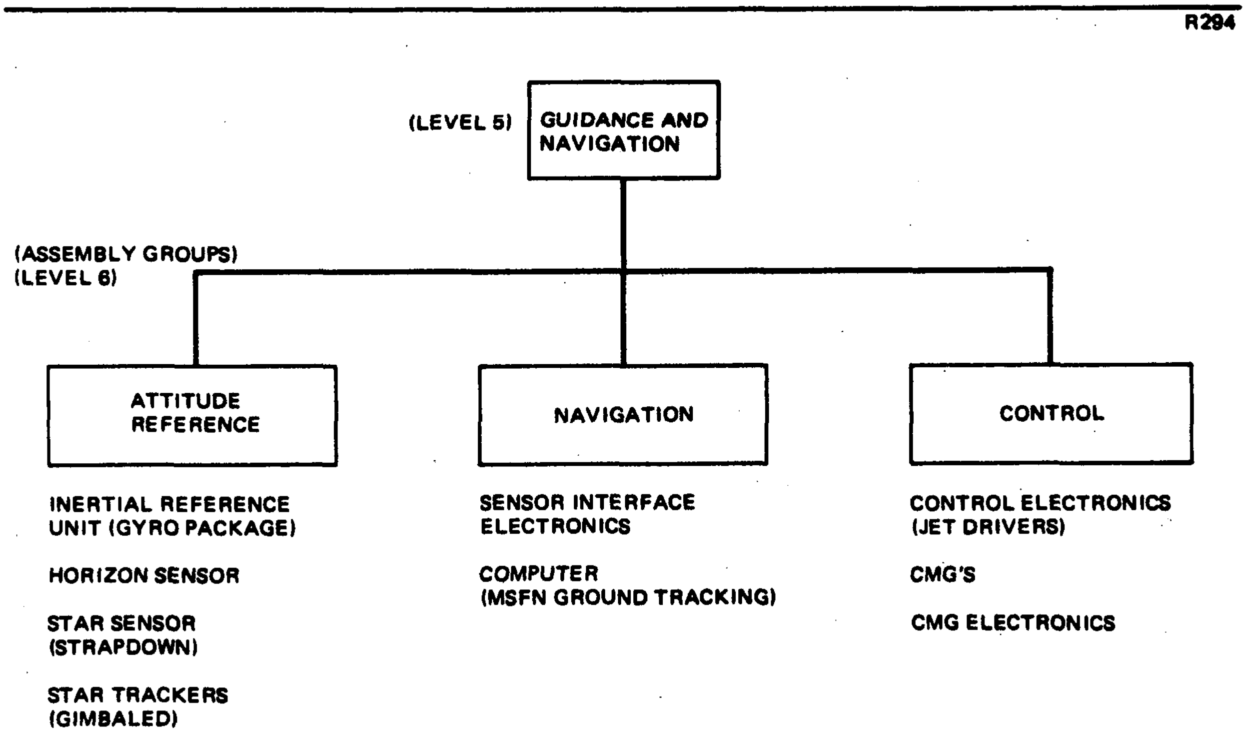


Figure 5-13. Guidance, Navigation, and Control Assembly Breakdown

Definition

The task definition of this WBS box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

There are none in addition to those in Section 2. 1. 2.

5. 5. 2 Costs

5. 5. 2. 1 Space Station Modules

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Cost Estimate

The Total Cost is estimated to be $6 million, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $5 million, will begin 66 months prior to the milestone launch date of October 1980, and will require 52 months for completion.

Production—It is estimated that the production effort will cost $1 million, will begin 31 months prior to the milestone launch date of October 1980, and will require 13 months for completion.

Operations—It is estimated that the operation effort will cost less than $0. 5 million, will begin 19 months prior to the milestone launch date of October 1980, and will continue for 12 months.

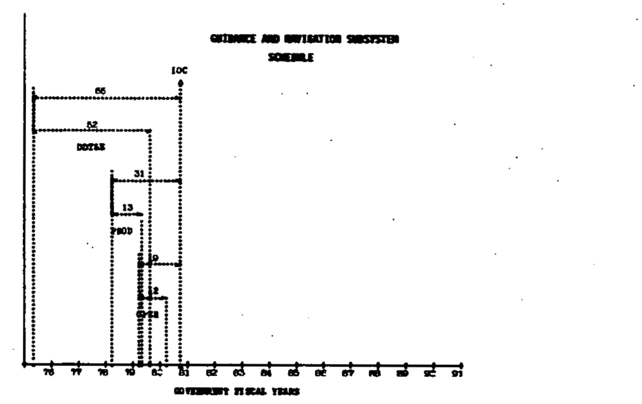
Funding Distribution

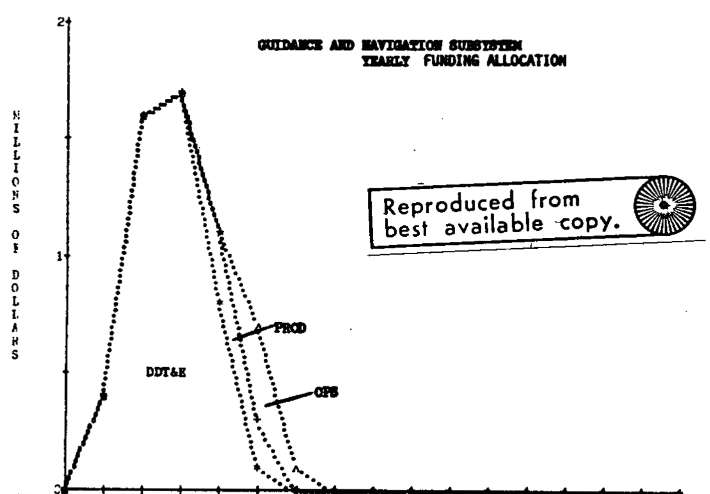
Figure 5-14 is a summary chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government fiscal year (midyear plot). DDT&E funding has been spread using a 60 percent spread function, while production funding was spread at 40 percent, and operations funding is based on a composite spread function.

GUIDANCE AND NAVIGATION SUBSYSTEM	TECHNICAL DESCRIPTION			WBS 2X75X46
MAJOR SUBASSEMBLY/GROUP	NO. OF EQUIV. UNITS	TOTAL WEIGHT (LB.)	AVE. POWER (WATTS)	CHARACTERISTICS
Attitude Control				
Inertial Reference	.2	4	27	
Horizon Sensor	.2	3	1	
Precision Reference				
Star Tracker	.5	40	2	
Star Sensor	.5	8	4	
Alignment Monitor	.5	15	5	

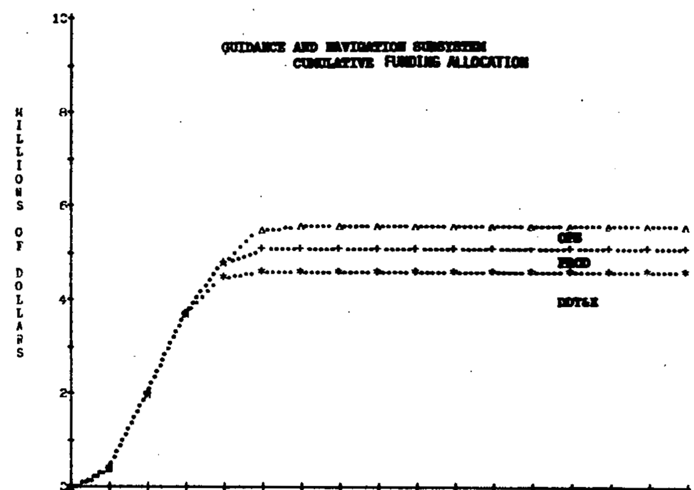
Additional Cost Considerations

Technology - Current	Similarity to Existing Units
Commonality	Complexity
Rate	Accuracy
Power	Reliability
Quantity - Subassemblies/Components	Maintainability





GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT·E	.4	1.6	1.7	.8	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.0	.0	.3	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.0	.4	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	.4	1.6	1.7	1.1	.7	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT·E	.4	2.0	3.7	4.5	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
PROD	.0	.0	.0	.3	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5
OPER	.0	.0	.0	.0	.4	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5
TOTAL	.4	2.0	3.7	4.8	5.5	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6

Figure 5-14. Guidance and Navigation Subsystem Summary Chart

5.5.2.1.1 Power/Subsystems Module

The estimated cost of the guidance and navigation subsystem for this module is as follows:

1972 Dollars in Millions			
DDT&E	Production	Operations	Total
5	1	0	6

5.5.2.1.2 Crew/Operations Module

The estimated cost of the guidance and navigation subsystem for this module is as follows:

1972 Dollars in Millions			
DDT&E	Production	Operations	Total
0	0	0	0

5.5.2.1.3 GPL Module

The estimated cost of the guidance and navigation subsystem for this module is as follows:

1972 Dollars in Millions			
DDT&E	Production	Operations	Total
0	0	0	0

5.5.3 Schedule

The schedule for the Space Station module G/N subsystem is shown in Figure 5-15. This schedule identifies equivalent subsystem-level equipment requirements (Table 5-7) and development activities required to design, test, and produce the subsystem. The schedule provides major milestones, key events, and critical actions pertaining to the subsystem.

The G/N subsystem design engineering starts at Phase C/D ATP. Major subcontractor ATP occurs 8 months into Phase C/D to establish the design requirements and design approach required for Preliminary Design Review (PDR). The engineering release (ER) for the G/N subsystem occurs 27 months after Phase C/D ATP and is 3 months prior to the Space Station module system ER final date.

2

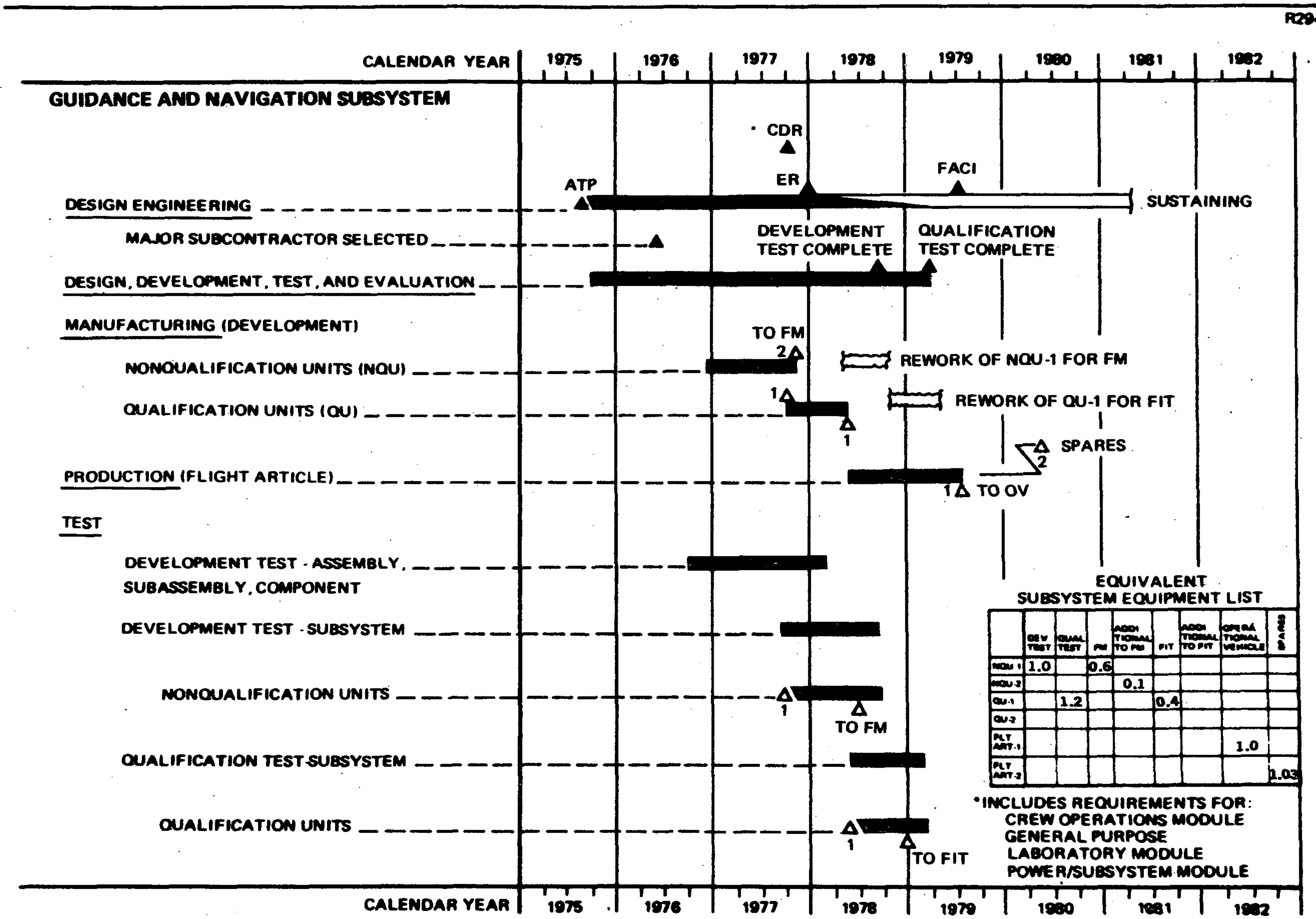


Figure 5-15. Guidance and Navigation Subsystem Schedule (ISS Only)

Table 5-7

GUIDANCE, NAVIGATION, AND CONTROL EQUIVALENT SUBSYSTEM EQUIPMENT LIST LEGEND

	Development Test	Qualification Test	FM	Additional to FM	FIT	Additional to FIT	Opertional Vehicle	Spares
NQU-1	1.0		0.6					
QU-1		1.2			0.4			
FA-1							1.0	
FA-2								1.031

The Critical Design Review (CDR) occurs 2 months before ER. The First Article Configuration Inspection (FACI) is performed at the time of delivery of the flight hardware August 1979. The DDT&E begins with Phase C/D ATP and ends at qualification test completion in April 1979.

The manufacturing time span begins with the nonqualification units in November 1976 and is completed with the manufacture of the production units for spares in May 1980. One nonqualification unit is produced and used in development testing (1-year duration) of the subsystem. Four months before completion of the test, approximately 60 percent of the unit is shipped to the functional model (FM). A second nonqualification unit is shipped directly to the FM upon completion of manufacture. One qualification unit is produced for the qualification testing (9-month duration). Three months before completion of the qualification test, approximately 40 percent of the unit is shipped to the flight integration tool (FIT) for integration and testing. Additional testing is performed early in the development phase at the component, subassembly, and assembly levels.

The G/N subsystem uses several unique design approaches in sensing, computing, and control actuation that require both unique technical capabilities and special attention. Key items are:

A. G/N software integration

B. G/N software development

C. Maintainable control moment gyro design

D. Dynamic analysis

Mechanical designs for a maintainable CMG are expected to be developed by SRT programs. Integration of CMG's with such design features will require special attention to installation location, access, maintenance procedure, and fault isolation. Maintainable CMG's will feature on-orbit replacement of the bearings spin motors and torques since these components are life limited. Considerable savings in logistics cost can be anticipated over a 10-year program with this design approach.

Integration of the G/N computer functions into the subsystem, with the accompanying software to perform computation of attitude reference, navigation, station attitude control, subsystem self-check, instrument calibration, etc., will require specialized technical capabilities in digital computer, interface, and software development and integration. The key to success in accomplishing this integration is good technical coordination based on sound specifications. Potential problems are expected in the interface compatibility areas both in hardware and software.

Dynamic analysis and simulation of the Space Station and control system for the zero-g operations will require special attention and technical capabilities. Detail structural dynamic characteristics of the station will not be available early in the program. The control system design approach must allow for adaptation to the eventually defined dynamic characteristics of the station. Analysis capability early in the program will enhance the confidence in the control system design approach. Failure to perform adequate analysis and simulation will increase the probability of major design changes and redesign of the G/N subsystem.

5.6 COMMUNICATIONS SUBSYSTEM (WBS 2 x 75 x 07)

5.6.1 Summary

The Space Station communications subsystem provides:

A. Space Station/ground communications

B. Space Station/shuttle communications

C. Space Station/RAM communications

It consists of antennas, amplifiers, receivers, transmitters with appropriate switching and multiplexing units, TV cameras, audio control, etc. This subsystem is illustrated in the WBS assembly level breakdown in Figure 5-16.

Definition

The task definition of this WBS is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

There are none in addition to those in Section 2. 1. 2.

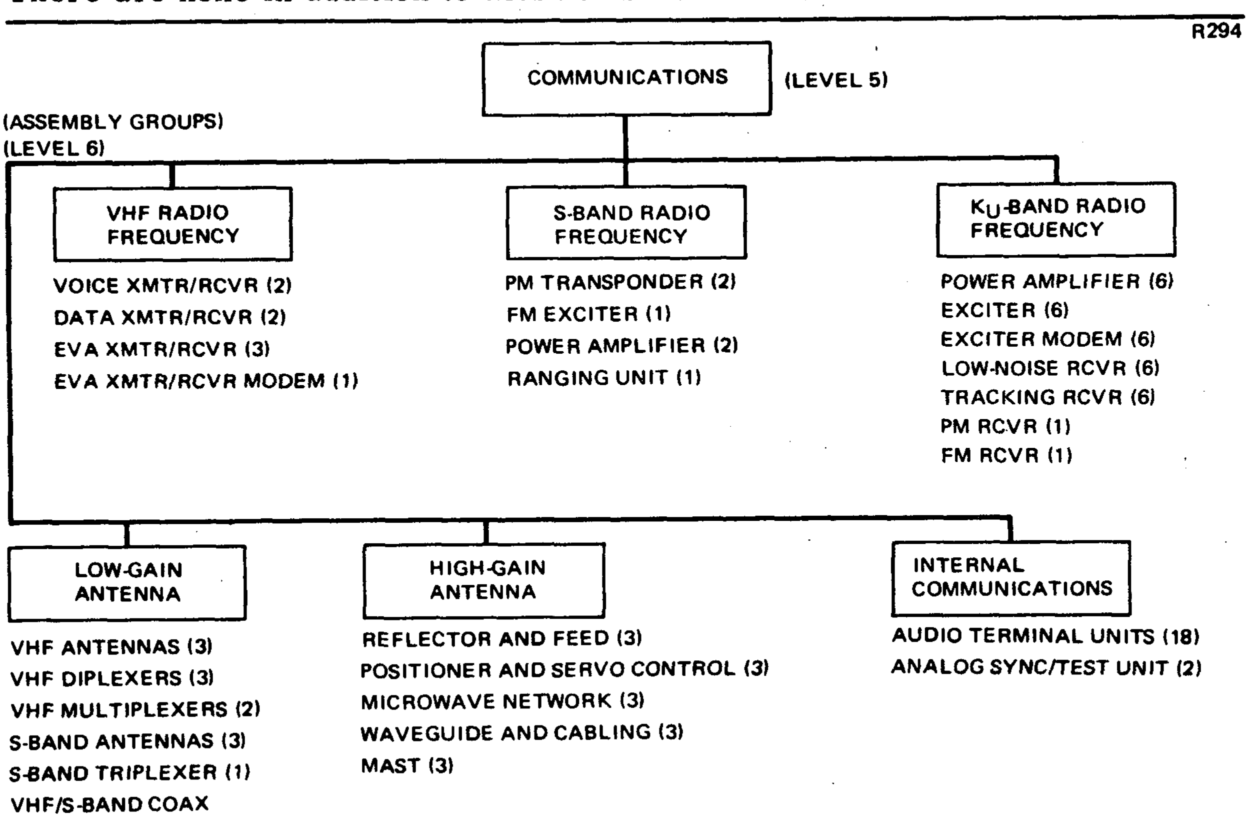


Figure 5-16. Communications Subsystem Assembly Group Breakdown

5.6.2 Costs

5.6.2.1 Space Station Modules

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Cost Estimate

The total cost is estimated to be $59 million, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $39 million, will begin 66 months prior to the milestone launch date of October 1980, and will require 54 months for completion.

Production—It is estimated that the production effort will cost $10 million, will begin 35 months prior to the milestone launch date of October 1980, and will require 16 months for completion.

Operations—It is estimated that the operation effort will cost $10 million, will begin 22 months prior to the milestone launch date of October 1980, and will continue for 15 months.

Funding Distribution

Figure 5-17 is a summary chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government fiscal year (midyear plot). DDT&E funding has been spread using a 60 percent spread function, while production funding was spread at 40 percent, and operations funding is based on a composite spread function.

5.6.2.1.1 Power/Subsystems Module

The estimated cost of the communications subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
11	3	3	17

COMMUNICATIONS SUBSYSTEM — TECHNICAL DESCRIPTION — WBS 2E75E07

MAJOR SUBASSEMBLY/GROUP	NO. OF EQUIV. UNITS	TOTAL WEIGHT (LB.)	AVE. POWER (WATTS)	CHARACTERISTICS
RF Communications				
VHF RF Assembly Group	1	983	387	Includes Voice Transmitter/RCVR. Modem, Data Transmitter Receiver, EVA Transmitter Received Modem, Ranging Unit
S-Band RF Assembly Group	1	39	13	Includes Transponder Modem, Exciter and Modem, Power Amplifier
SHF RF Assembly Group	1	73	32	Includes S-Band Video Receiver, S-Band Data Receiver, S-Band Wideband Receiver, K_u Exciter Modem
Low Gain Antenna Group	3	121	3	Includes VHF Antenna Elements, VHF Diplex Multi-Switch, S-Band Antenna, S-Band Triplex Switch, VHF S-Band Coaxial
High Gain Antenna Group	3	705	300	Includes Reflector and Feed, Position Servo Com., Thermal Control, K_u Power Amplifier, K_u Exciters, K_u Lo Noise Receiver, S-Band Tracking Receiver, Microwave Assembly
Internal Communications				
Internal Comm. Assembly Group	15	77	46	Includes Audio Terminals, Analog Synch. Test

Additional Cost Considerations

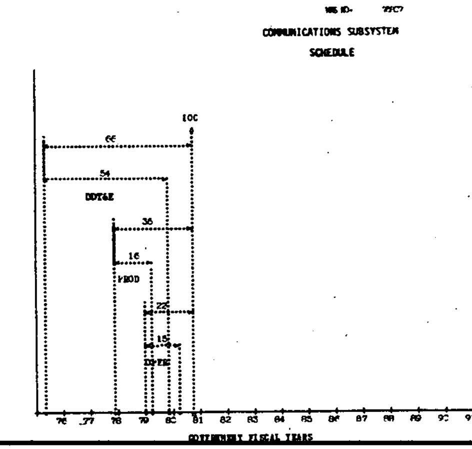
Technology - Generally Current, Some Applications Technology Development Required

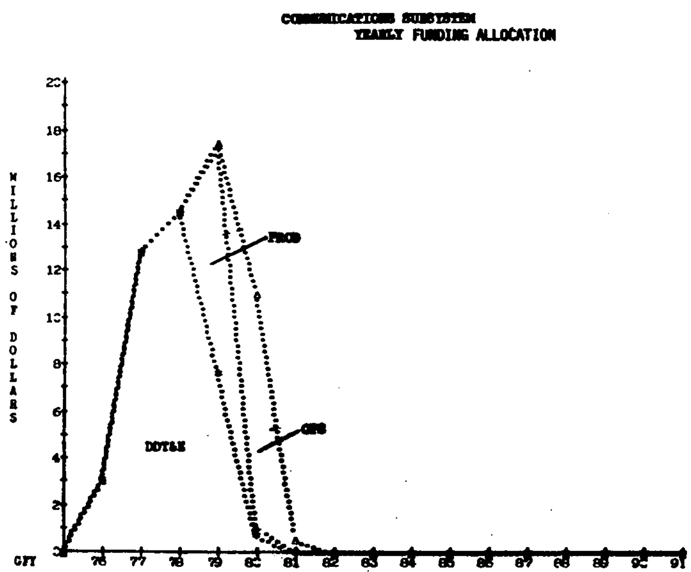
Similarity to Existing Units	Complexity
Commonality	Reliability
Method of Fabrication	Maintainability
Multiple Usage	Quantity - Subassemblies/Components

WBS ID- 2EC7

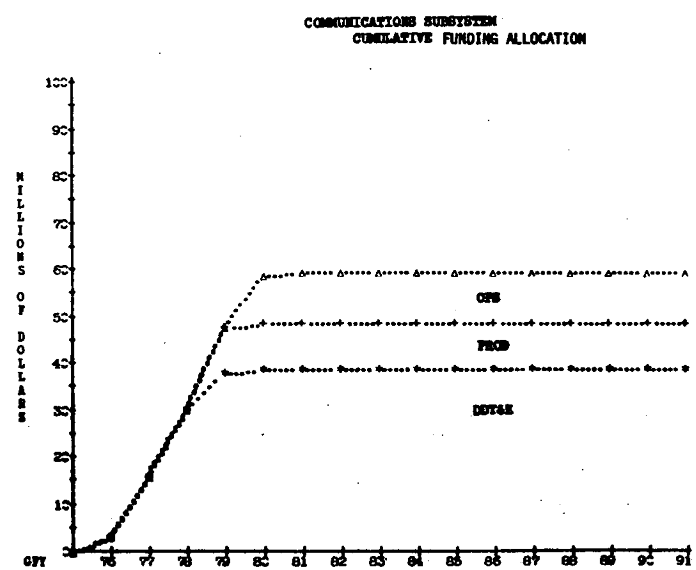
COMMUNICATIONS SUBSYSTEM

SCHEDULE





GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT•E	3•1	12•8	14•5	7•6	•7	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
PROD	•0	•0	•0	9•6	•3	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
OPER	•0	•0	•0	•3	10•0	•6	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
TOTAL	3•1	12•8	14•5	17•5	11•0	•6	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT•E	3•1	15•9	30•4	38•0	38•7	38•7	38•7	38•7	38•7	38•7	38•7	38•7	38•7	38•7	38•7	38•7
PROD	•0	•0	•0	9•6	9•9	9•9	9•9	9•9	9•9	9•9	9•9	9•9	9•9	9•9	9•9	9•9
OPER	•0	•0	•0	•3	10•3	10•9	10•9	10•9	10•9	10•9	10•9	10•9	10•9	10•9	10•9	10•9
TOTAL	3•1	15•9	30•4	47•9	58•9	59•5	59•5	59•5	59•5	59•5	59•5	59•5	59•5	59•5	59•5	59•5

Figure 5-17. Communications Subsystem Summary Chart

5.6.2.1.2 Crew/Operations Module

The estimated cost of the communications subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
28	7	7	42

5.6.2.1.3 GPL Module

The estimated cost of the communications subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
0	0	0	0

5.6.3 Schedule

The schedule for the Space Station module communications subsystem is shown in Figure 5-18. This schedule identifies equivalent subsystem level equipment requirements (Table 5-8) and development activities required to design, test, and produce the subsystem. The schedule provides major milestones, key events, and critical actions related to the subsystem.

The communications design engineering will start at Phase C/D ATP. Major subcontractor ATP occurs 9 months into Phase C/D to establish the design requirements and design approach required for Preliminary Design Review (PDR). The ER for the communications subsystem occurs 24 months after Phase C/D ATP, and is 6 months before the Space Station Modules system ER final date. The CDR occurs 2 months before ER. The FACI is performed at the time of delivery of the flight hardware in August 1979. The DDT&E begins with Phase C/D ATP design and ends at qualification test completion in April 1979.

The manufacturing time span begins with the nonqualification units in November 1976 and is completed with the manufacture of the production units for spares in May 1980. One nonqualification unit is produced and used in

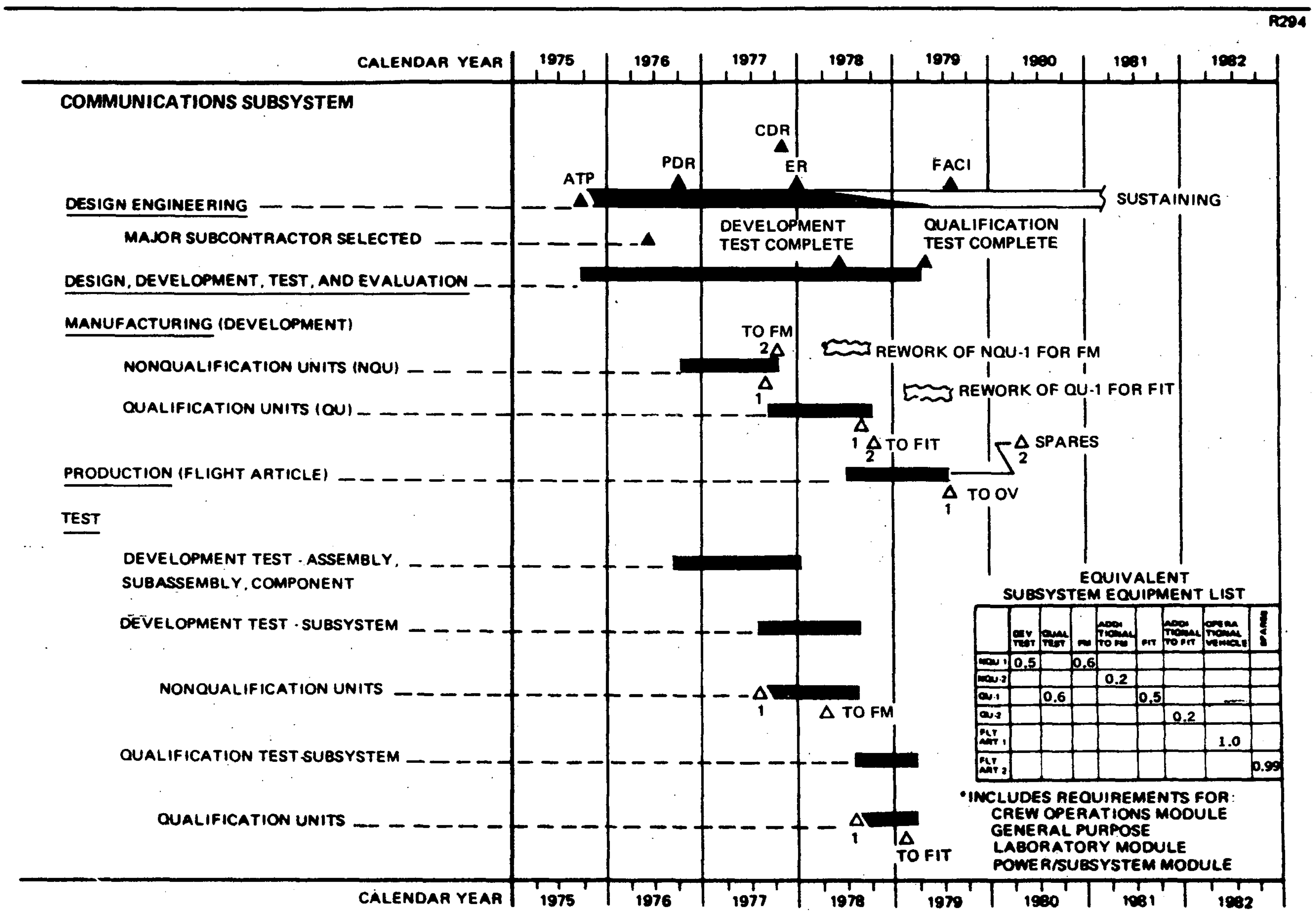


Figure 5-18. Communications Subsystem Schedule (ISS Only)

Table 5-8

COMMUNICATIONS EQUIVALENT SUBSYSTEM EQUIPMENT LIST LEGEND

	Development Test	Qualification Test	FM	Additional to FM	FIT	Additional to FIT	Operational Vehicle	Spares
NQU-1	0.5		0.6					
NQU-2				0.2				
QU-1		0.6			0.5			
QU-2						0.2		
FA-1							1.0	
FA-2								1.91

development testing of the subsystem for a 12-month period. At the end of 8 months of the test 80 percent of the unit is then delivered to the functional module. A second nonqualification unit (0.2 equivalent) is shipped directly to the FM upon completion of manufacture. One qualification unit is produced for the qualification testing of 9-months duration. Three months before completion of the qualification test, approximately 80 percent of the unit is shipped to the flight integration tool (FIT) for integration and testing. Additional testing is performed early in the development phase at the component, subassembly, and assembly levels.

The mission requirements for the Space Station have imposed reliability levels on the communications subsystem which are, in many cases, several orders of magnitude greater than previously encountered. To meet these requirements, it will be necessary to apply all of the known techniques for the design and production of reliable equipment and in many cases extend these techniques to that which will be available in the 1975 to 1980 time period. In certain areas, this will require technology investigations to extend the state of the art and provisions for achieving the necessary reliability levels.

The high-gain antenna system which is located externally is particularly important. The high-gain positioner contains electromechanical and mechanical components that are quite susceptible to failure. In addition, the K_u-band RF equipment is located externally at the end of the antenna mast.

According to preliminary estimates of the assembly-level operational mean-time-between-failure, the K_u-band transmitters used as the primary communications link from the Space Station to the relay satellite appear to have the highest failure rate. Effort should be initiated early to ensure that higher reliability components will be available.

There are several elements of the communications subsystem which have unique testing and installation requirements; one such is the high-gain antenna assembly. It is not feasible to perform operational tests of the complete high-gain antenna assembly after it has been installed on the Space Station. Therefore, it will be necessary to verify system performance and perform simulated operational-procedure tests at subcontractor facilities. The flight hardware would be mated to the flight vehicle at the launch site. This procedure was used during the Apollo Program to mate the high-gain antenna system to the service module.

To verify the omnidirectional antenna radiation patterns, either a full-scale or a partial-scale vehicle model must be provided and the patterns cut on an antenna range. This model must accurately reflect the outboard vehicle profile in all respects to perform valid tests. The capability to perform this type of testing exists within MDAC-WD.

In addition to the RF system (excluding the antennas) and onboard telephone system development testing, extensive integration testing to verify compatibility with the other vehicle subsystems will be required during the functional model (FM) and flight integration tool (FIT) tests.

Before preparing firm specifications, the performance requirements and characteristics of the other interfacing program elements must be firmly defined. This includes the shuttle, free-flying experiment modules, and the data relay satellite. The transmitter power output, receiver sensitivity, and antenna system gain are all affected by the performance requirements and characteristics of the other program elements. In addition, the interfaces and characteristics of the other vehicle subsystems must be firmly established.

5.7 DATA MANAGEMENT SUBSYSTEM (WBS 2 x 75 x 47)

5.7.1 Summary

The data management subsystem consists of all the necessary equipment to transfer, store, and process data to and from users and subsystems. It is a modularized multiprocessor specifically consisting of processors, memory storage units, switching units, peripheral devices, data adapters, coders, decoders, time synchronous generator, film scanners and reducers, analog tape storage, search and control equipment, signal conditioning and demodulation equipment, and entertainment units.

This subsystem is illustrated in the WBS assembly-level breakdown in Figure 5-19.

Definition

The task definition of this WBS box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

There are none in addition to those in Section 2.1.2.

5.7.2 Costs

5.7.2.1 Space Station Modules

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Cost Estimate

The total cost is estimated to be $99 million, as follows:

DDT&E—It is estimated that the DDT&E effort will cost $71 million, will begin 66 months prior to the milestone launch date of October 1980, and will require 54 months for completion.

Production—It is estimated that the production effort will cost $14 million, will begin 37 months prior to the milestone launch date of October 1980, and will require 18 months for completion.

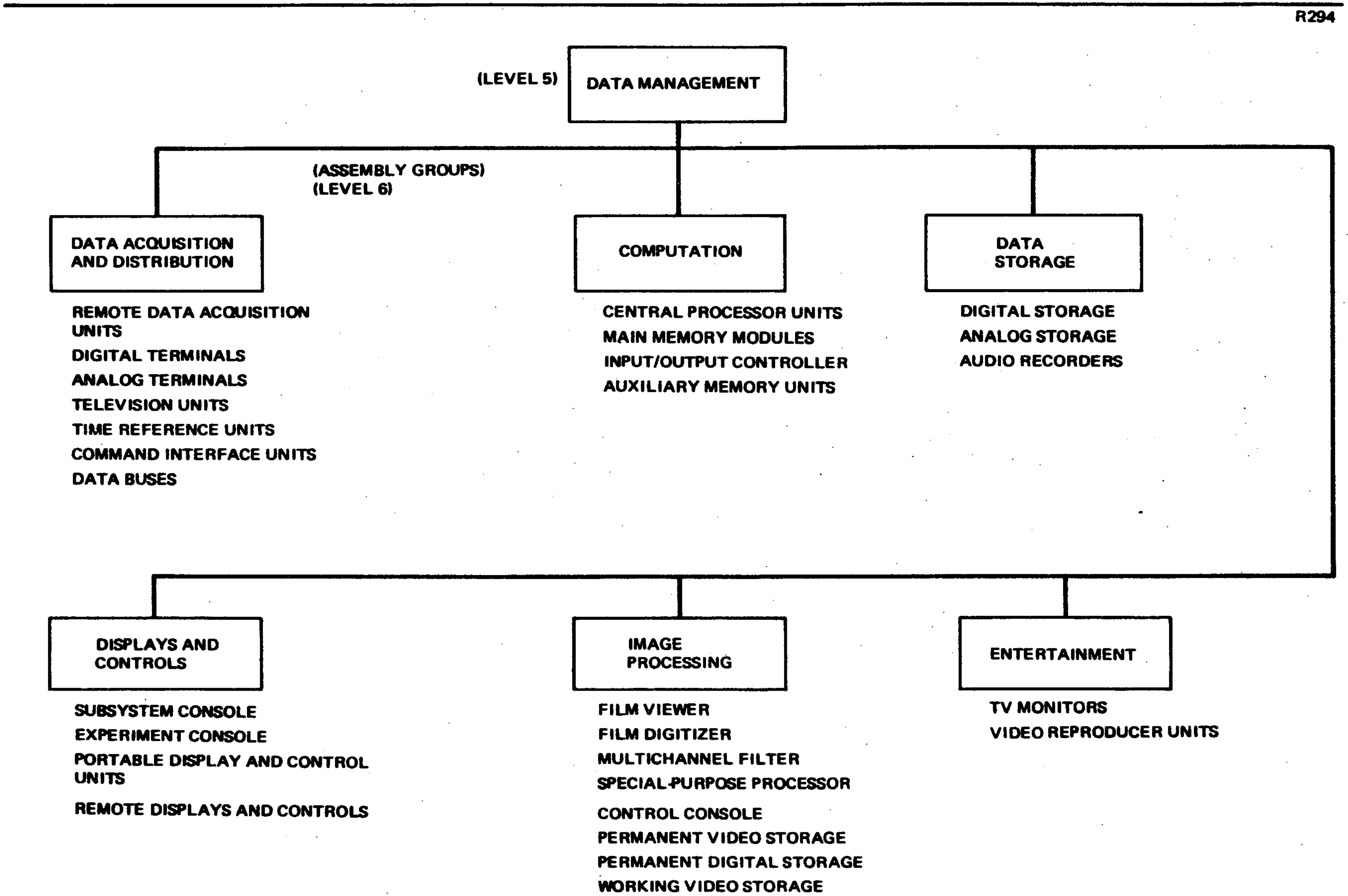


Figure 5-19. Data Management Subsystem Assembly Group Breakdown

Operations—It is estimated that the operation effort will cost $14 million, will begin 22 months prior to the milestone launch date of October 1980, and will continue for 31 months.

Funding Distribution

Figure 5-20 is a summary chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government fiscal year (midyear plot). DDT&E funding has been spread using a 60 percent spread function, while production funding was spread at 40 percent, and operations funding is based on a composite spread function.

5.7.2.1.1 Power/Subsystems Module

The estimated cost of the data management subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
14	3	3	20

5.7.2.1.2 Crew/Operations Module

The estimated cost of the data management subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
21	4	4	29

5.7.2.1.3 GPL Module

The estimated cost of the data management subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
36	7	7	50

5.7.3 Schedule

The schedule for the Space Station module DMS is shown in Figure 5-21. This schedule identifies equivalent subsystem-level equipment requirements (Table 5-9) and development activities required to design, test, and produce the subsystem.

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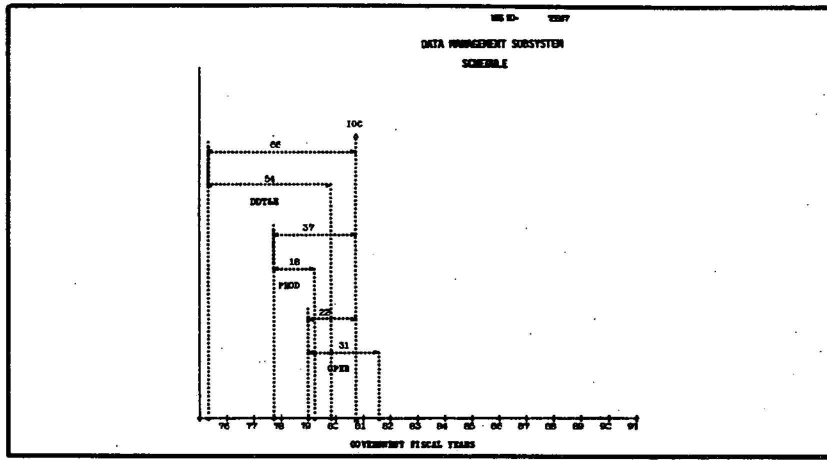
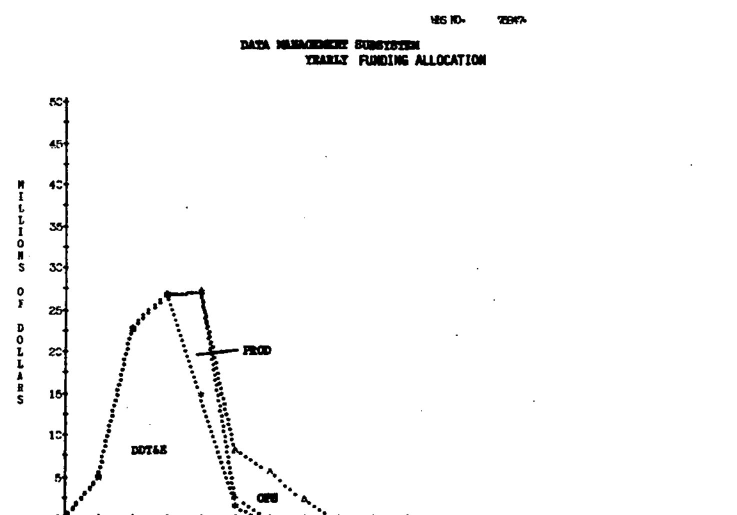
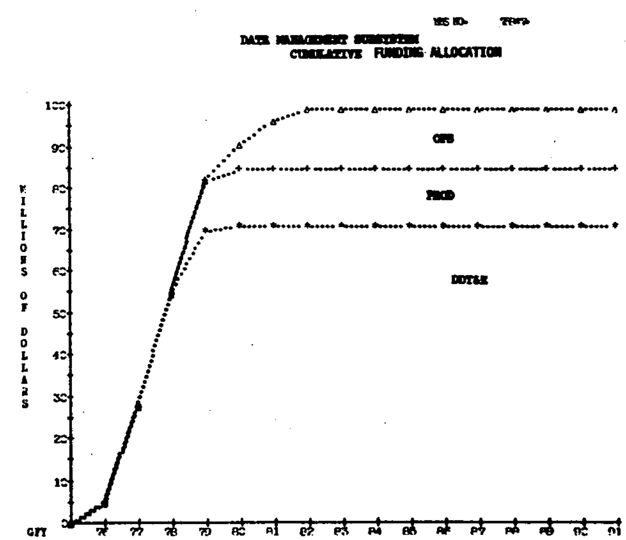
DATA MANAGEMENT SUBSYSTEM	TECHNICAL DESCRIPTION			WBS 2275X07
MAJOR SUBASSEMBLY/GROUP	NO. OF EQUIV. UNITS	TOTAL WEIGHT (LB.)	AVG. POWER (WATTS)	CHARACTERISTICS
Computation				
Subsystem Computer	2	270	510	
Experiment Computer	2	250	485	
Data Acquisition and Transfer				
Data Bus		115	327	7 Analog and 16 Digital Terminals
Timing (Time Ref. Units)	2	20	60	
RDAU	28	26	78	
Command		58	82	17 Command Decoders and 2-Command Interface
Television	12	120	36	
Image Processing				
Experiment Console	1	324	51	
Permanent Video Storage	1	100	25	
Permanent Digital Storage	1	40	10	
Work Video Storage	1	12	3	
Data Storage		470	425	Includes 3 Digital and 3 Analog Recorders
Display and Control				
Subsystem Console	2	975	996	
Experiment Console	2	975	996	
Portable Monitor and Control	2	400	48	
Crew Audio/Visual	9	180	45	
Software				254,000 Instructions

Technology - Current, Some Technology Development-Application Required



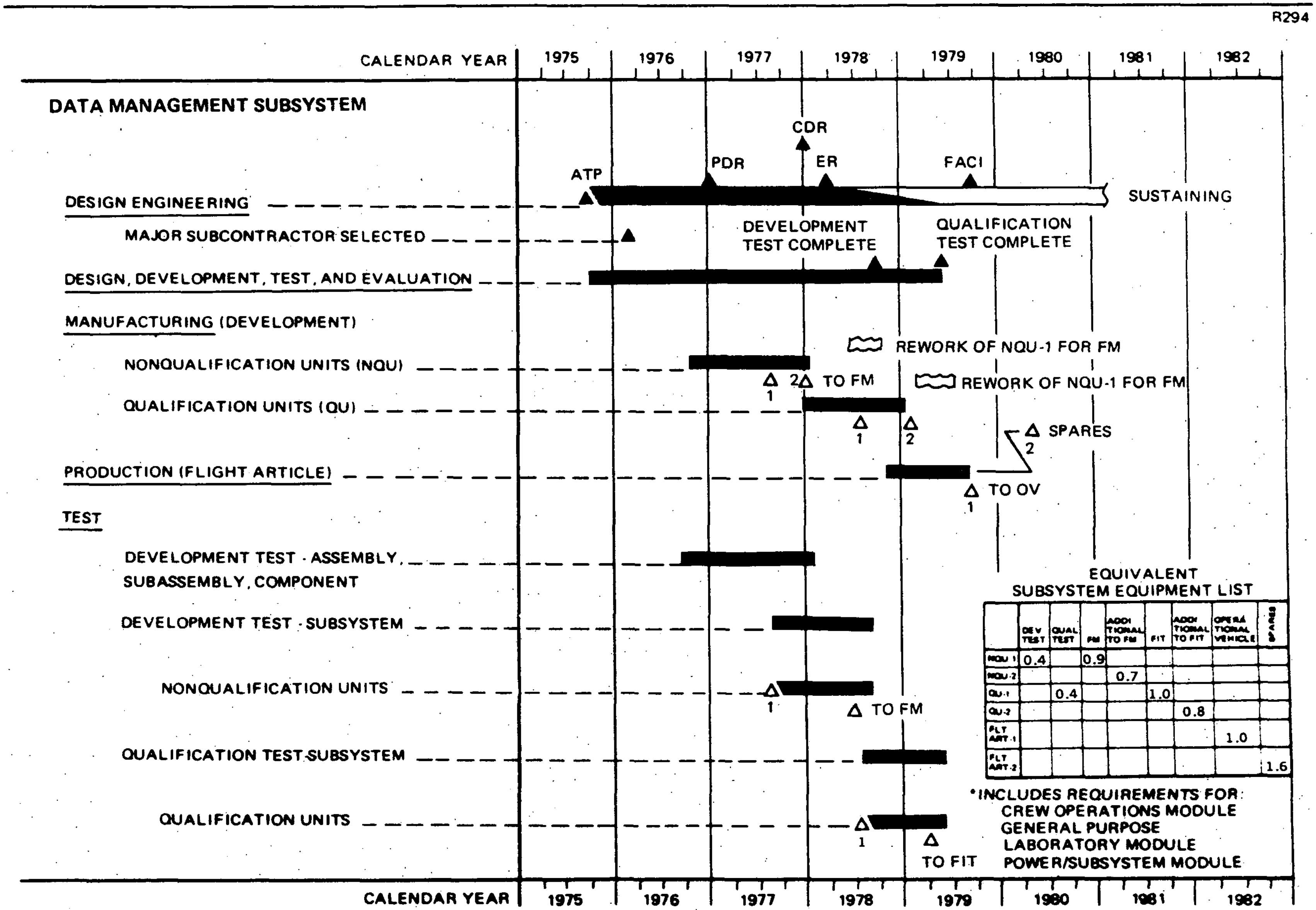


GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	5.0	22.9	26.9	14.8	1.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.0	.0	12.5	1.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.1	5.6	5.9	2.6	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	5.0	22.9	26.9	27.4	8.3	5.9	2.6	.0	.0	.0	.0	.0	.0	.0	.0	.0



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	5.0	27.9	54.8	69.6	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2	71.2
PROD	.0	.0	.0	12.5	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6
OPER	.0	.0	.0	.1	5.7	11.6	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
TOTAL	5.0	27.9	54.8	82.2	90.5	96.4	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0

Figure 5-20. Data Management Subsystem Summary Chart



	DEV TEST	QUAL TEST	FM	ADDITIONAL TO FM	FIT	ADDITIONAL TO FIT	OPERATIONAL VEHICLE	SPARES
NQU-1	0.4		0.9					
NQU-2				0.7				
QU-1		0.4			1.0			
QU-2						0.8		
FLT ART-1							1.0	
FLT ART-2								1.6

Figure 5-21. Data Management Subsystem Schedule (ISS Only)

Table 5-9

DATA MANAGEMENT EQUIVALENT SUBSYSTEM EQUIPMENT LIST LEGEND (ISS ONLY)

	Development Test	Qualification Test	FM	Additional to FM	FIT	Additional to FIT	Operational Vehicle	Spares
NQU-1	0.4		0.9					
NQU-2				0.7				
QU-1		0.4			1.0			
QU-2						0.8		
FA-1							1.0	
FA-2								1.610

The DMS design engineering starts at Phase C/D. The major subcontractor ATP occurs 7 months into Phase C/D in order to establish the design requirements and design approach required for PDR. The engineering release for the DMS occurs 30 months after Phase C/D ATP and is coincident with the final Space Station Modules system ER date. The CDR occurs 2 months before ER. The FACI is performed at the time of delivery of the flight hardware October 1979. The DDT&E begins with Phase C/D ATP and ends at qualification test completion July 1979.

The manufacturing time span begins with the nonqualification units in December 1979 and is completed with the manufacture of the qualification units for spares in May 1980. Two nonqualification units are produced. One is utilized in development testing (13-month duration) of the subsystem. Three months before completion 20 percent of the unit is shipped to the functional model. The second nonqualification unit is shipped directly to the functional model upon completion of manufacture. One qualification unit is produced for the qualification testing (11-month duration). Three months before completion of the qualification test 20 percent of the unit is shipped to the FIT for integration and testing. A second unit (0.8 equivalent) is produced and shipped directly to the FIT 2 months before the first unit. Additional testing is performed early in the development phase at the component, subassembly, and assembly levels.

The development of special computation equipment (computer hardware) requires a different approach from that accorded other equipment. Consideration must first be given to the software interface, since the two are interdependent in providing a functioning subsystem.

Although hardware/software design should proceed in a somewhat parallel fashion, early definition of the hardware characteristics must first be established to allow software development. Characteristics such as subsystem architecture; operating and control procedures; instruction repertoire; and parameters such as time delays, instruction word formats and lengths, and instruction execution time must therefore be firmly controlled so as not to invalidate this development. This also implies that subsystem simulations and modeling activities required to develop characteristics such as queue lengths, time delays, and data rates must also be performed at an early date.

A second consideration (which is an outgrowth of the first) requires that standardization of at least some of these characteristics be established for both ground as well as Space Station Modules system equipment. This is required to allow development of the software during the design phase and compatibility during the operational phase. The result of these considerations is that computer hardware definition must be controlled at an early development stage compared to other equipment, for greater effort must be expended to achieve an equivalent design status.

Verification of the data bus concept will require special development emphasis. The concept of a data bus is not new: computer subsystems have used the technique for years and many study contracts, including simulations, have been performed. However, the dependence of the Space Station systems on the distribution system, and the large number of devices and their resultant composite data rates, require additional verification of the technique's acceptability before and during Phase C/D.

Improved definition of imagery requirements will require special attention. The early specification release data will be predicated on obtaining improved processing requirements from additional experiment definition. There is also a very desirable optical or spatial processing technique presently in the laboratory stage, which, if developed, would be preferentially employed on the Space Station.

5.8 CREW HABITABILITY SUBSYSTEM (WBS 2 X 75 X 59)

5.8.1 Summary

The crew habitability and protection subsystem (CH&PS) provides facilities and equipment for the crew housing and living. It includes the equipment and facilities for recreation, exercise, lighting, dining, hygiene, medical care, food, food storage, radiation and meteoroid protection, damage control and safety, crew living and sleeping quarters, and space suits.

The WBS assembly level breakdown for this subsystem is illustrated in Figure 5-22.

Definition

The task definition of this WBS box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

There are none in addition to those discussed in Section 2.1.2.

5.8.2 Costs

5.8.2.1 Space Station Modules

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Cost Estimate

The total cost, estimated to be $27.4 million, is broken down as follows:

DDT&E—It is estimated that the DDT&E effort will cost $14.7 million, will begin 66 months prior to the milestone launch date of October 1980, and will require 58 months for completion.

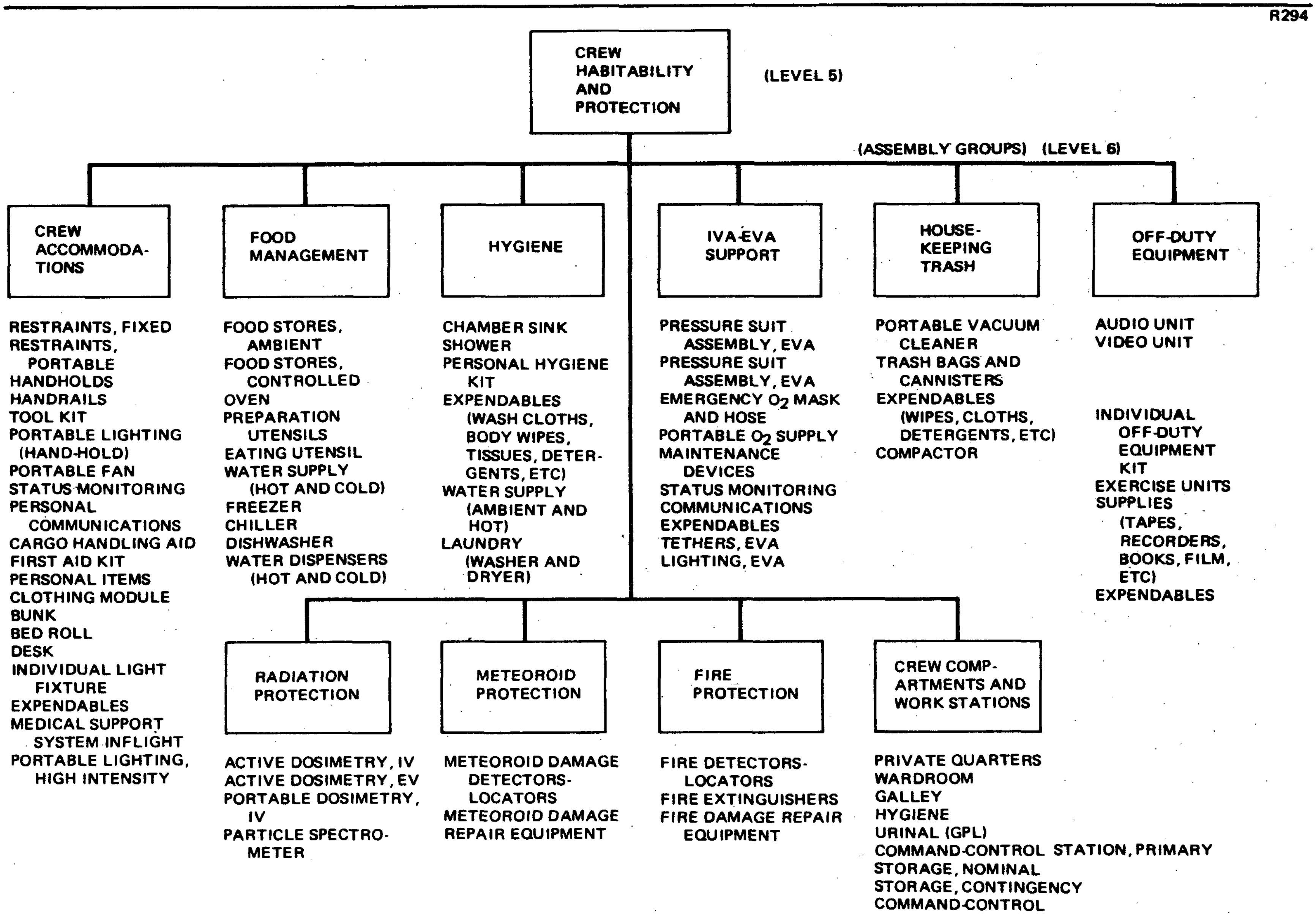


Figure 5-22. Crew Habitability Subsystem Assembly Breakdown

Production—It is estimated that the production effort will cost $6.8 million, will begin 32 months prior to the milestone launch date of October 1980, and will require 14 months for completion.

Operations—It is estimated that the operation effort will cost $5.9 million, will begin 21 months prior to the milestone launch date of October 1980, and will continue for 20 months.

Funding Distribution

Figure 5-23 is a summary chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government fiscal year (midyear plot). DDT&E funding has been spread using a 60 percent spread function, while production funding was spread at 40 percent, and operations funding is based on a composite spread function.

5.8.2.1.1 Power/Subsystems Module

The estimated cost of the crew habitability subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
1	0	0	2

5.8.2.1.2 Crew/Operations Module

The estimated cost of the crew habitability subsystem for this module is as follows:

1972 Dollars in Millions

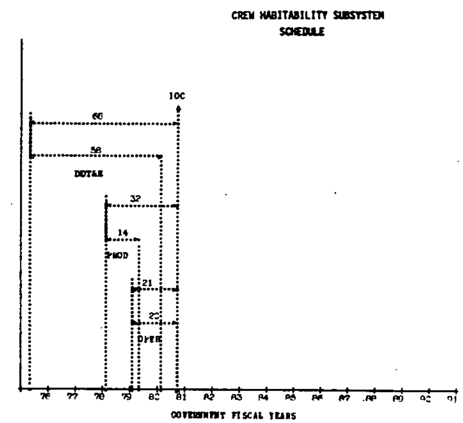
DDT&E	Production	Operations	Total
11	5	4	20

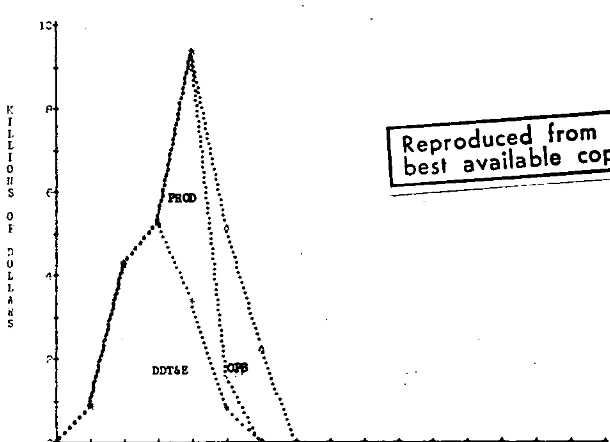
CREW HABITABILITY SUBSYSTEM	TECHNICAL DESCRIPTION	WBS 2X75X59
MAJOR SUBASSEMBLY/GROUP	TOTAL WEIGHT (LB.)	CHARACTERISTICS
Crew Accommodations	527	6 Crewmen
Food Management - Equipment	371	
Food	1153	Expendables
Radiation Protection	61	
Hygiene	340	
Meteoroid Protection	85	
IVA/EVA Support	122	
Fire Protection	100	
Housekeeping and Trash	184	
Off-Duty Equipment	188	
Crew Compartments and Work Stations	1035	
Lighting	647	1256 Watts

Additional Cost Considerations

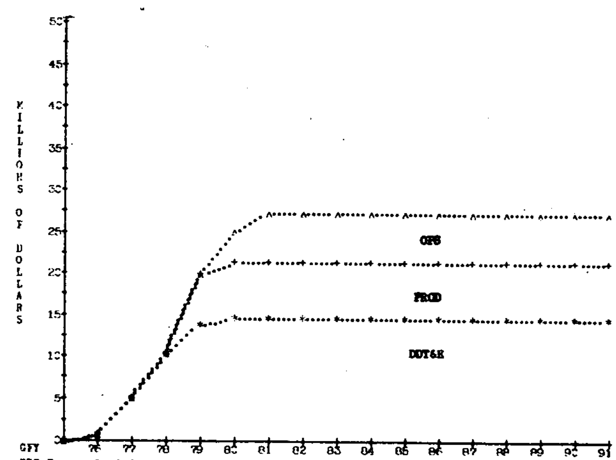
Technology - Generally Current; However, Development Technology required for Food Management, Crew Compartments and Work Stations, Crew Accommodations, and Radiation, Meteoroid and Fire Protection

Quantity - Subassemblies/Components	Commonality
Size/Material/Method of Fabrication	Safety
Similarity to Existing Units	Complexity
Multiple Usage	Shape





GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT•E	•9	4•3	5•3	3•4	•8	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
PROD	•0	•0	•0	6•0	•8	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
OPER	•0	•0	•0	•0	3•6	2•3	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0
TOTAL	•9	4•3	5•3	9•4	5•2	2•3	•0	•0	•0	•0	•0	•0	•0	•0	•0	•0



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT•E	•9	5•2	10•5	13•9	14•7	14•7	14•7	14•7	14•7	14•7	14•7	14•7	14•7	14•7	14•7	14•7
PROD	•0	•0	•0	6•0	6•8	6•8	6•8	6•8	6•8	6•8	6•8	6•8	6•8	6•8	6•8	6•8
OPER	•0	•0	•0	•0	3•6	5•9	5•9	5•9	5•9	5•9	5•9	5•9	5•9	5•9	5•9	5•9
TOTAL	•9	5•2	10•5	19•9	25•1	27•4	27•4	27•4	27•4	27•4	27•4	27•4	27•4	27•4	27•4	27•4

Figure 5-23. Crew Habitability Subsystem Summary Chart

5.8.2.1.3 GPL Module

The estimated cost of the crew habitability subsystem for this module is as follows:

1972 Dollars in Millions

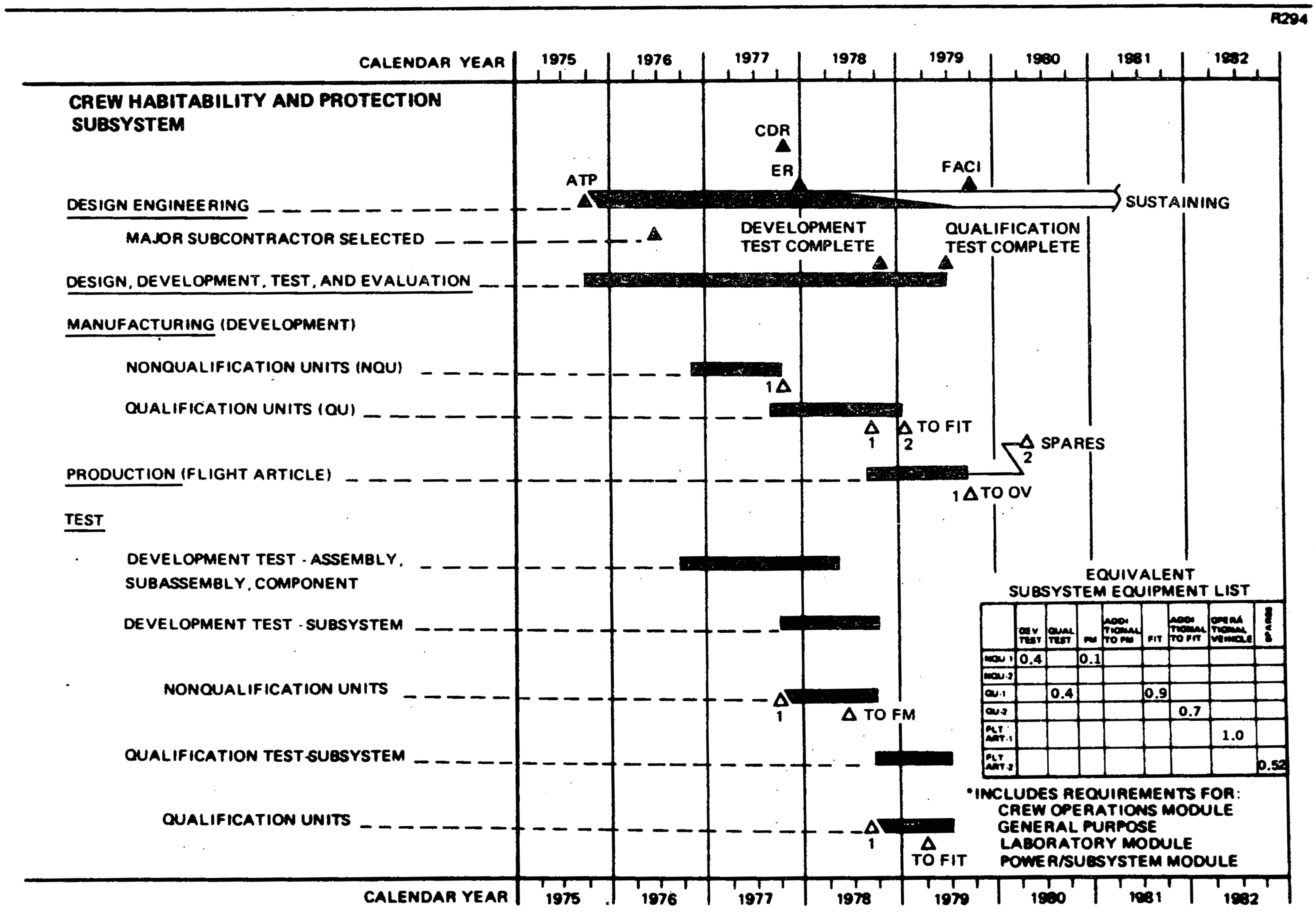
DDT&E	Production	Operations	Total
2	1	1	5

5.8.3 Schedule

The schedule for the Space Station module CH&PS is shown in Figure 5-24. This schedule identifies equivalent subsystem-level equipment (Table 5-10) and development activities required to design, test, and produce the subsystem. The schedule provides major milestones, key events, and critical actions pertaining to the subsystem.

CH&PS design engineering starts at Phase C/D ATP. The major subcontractor ATP occurs 9 months into Phase C/D in order to establish the design requirements and design approach required for PDR. The engineering release for the CH&PS occurs 27 months after Phase C/D ATP and 3 months prior to the final Space Station module system ER date. The CDR occurs 2 months before ER and FACI is performed at the delivery of the flight hardware in October 1979. The DDT&E begins with Phase C/D ATP and ends at qualification test completion in August 1979.

The manufacturing time span begins with the nonqualification units in October 1976 and is completed with the manufacture of the production units for spares in May 1980. One nonqualification unit is produced and used in subsystem development testing (1-year duration). Four months prior to the completion of the test, 10 percent of the unit is shipped to the functional model and one qualification unit is produced for the qualification testing (10-month duration). Three months prior to completion of the qualification test, 20 percent of the unit is shipped to the FIT for integration and testing. A second qualification unit (0.7 equivalent) is shipped to the FIT upon completion of manufacture. Additional testing is performed early in the development phase at the component, subassembly, and assembly levels.



	DEV TEST	QUAL TEST	FM	ADDITIONAL TO FM	FIT	ADDITIONAL TO FIT	OPERATIONAL VEHICLE	SPARES
NQU 1	0.4		0.1					
NQU 2								
QU 1		0.4			0.9			
QU 2						0.7		
FLT ART 1							1.0	
FLT ART 2								0.52

Figure 5-24. Crew Habitability and Protection Subsystem Schedule

Table 5-10

CREW HABITABILITY AND PROTECTION EQUIVALENT SUBSYSTEM EQUIPMENT LEGEND

	Development Test	Qualification Test	FM	Additional to FM	FIT	Additional to FIT	Operational Vehicle	Spares
NQU-1	0.4		0.1					
QU-1		0.4			0.9			
QU-2						0.7		
FA-1							1.0	
FA-2								0.52

To develop a CH&PS which will be optimum in zero gravity, a wide diversity of technology is required. It will be necessary to apply all of the known techniques for the design and production of reliable equipment and in many cases extend these techniques to that which will be available in the 1975-to-1980 time period. In certain areas, this will require technology investigations to extend the state of the art and to achieve the necessary reliability levels, particularly in accommodating female crew members and scientists.

The key problems at the assembly level are the development of items such as a highly efficient and reliable microwave and infrared oven; food freezer and refrigerator; dishwasher and dryer; full-body shower; zero-g sink; laundry washer and dryer; trash processor and compactor; devices for detection, warning, and repair of meteoroid damage; fire detection, warning, and extinguishing units; and dispensary equipment for the diagnosis and treatment of injuries, illnesses, and dental emergencies. These items represent potential development difficulties and will require SRT funding.

There are several assemblies of the CH&PS which have unique testing requirements as a result of the high reliability levels imposed upon the electromechanical, electrical, mechanical, pneumatic, and hydraulic components which are susceptible to failure. It is not feasible to perform operational tests of all CH&PS assemblies after installation in the Space Station. Therefore, it will be necessary to verify subsystem performance and to perform simulated operational procedural tests at the subcontractor's facilities. In addition to the individual assembly tests, extensive compatibility tests of various assemblies integrated with each other and with the EC/LS subsystem are required prior to final qualification of the CH&PS assemblies.

To achieve these integrated CH&PS tests with a simulated installation, the special, full-scale, two-deck simulated EC/LS subsystem test model will be used as a combined CH&PS test bed with the EC/LS subsystem. This test bed will contain complete EC/LS subsystem and CH&PS and will be used to verify the design and to functionally qualify the subsystems for inclusion on the flight article.

Unique installation requirements exist for the 30-day supplies of food required initially with the Initial Space Station and the 30-day supplies plus the 30-day back-up supplies delivered to the Space Station on orbit by the LOG M's to support each crewman. Tests simulating food environmental conditions and elapsed time between installation and launch will be performed at the subcontractor's food-processing facility.

5.9 STABILIZATION AND ATTITUDE CONTROL SUBSYSTEM (WBS 2 x 75 x 56)

5.9.1 Summary

The stabilization and attitude control subsystem functions to:

A. Generate attitude reference information for attitude control, experiments, communications, and guidance and navigation.

B. Provide all attitude capability.

C. Generate commands to reaction jets for attitude and translation control.

D. Maintain station orientation, nominally trimmed horizontal (Y).

It is composed of attitude and rate sensors; electronics for sensor, computer, experiments, and reaction jet interfaces; display and control elements; and control moment gyros. It utilizes the computation capability of the data management subsystem.

This subsystem is illustrated in combination with the guidance and navigation subsystem in Section 5.5.

Definition

The task definition of this WBS box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

There are none in addition to those in Section 2.1.2.

5.9.2 Costs

5.9.2.1 Space Station Modules

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Cost Estimate

The total cost, estimated to be $67 million, is broken down as follows:

DDT&E—It is estimated that the DDT&E effort will cost $29.1 million, will begin 66 months prior to the milestone launch date of October 1980, and will require 53 months for completion.

Production—It is estimated that the production effort will cost $15.9 million, will begin 34 months prior to the milestone launch date of October 1980, and will require 17 months for completion.

Operations—It is estimated that the operations effort will cost $22.1 million, will begin 20 months prior to the milestone launch date of October 1980, and will continue for 12 months.

Funding Distribution

Figure 5-25 is a summary chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government fiscal year (midyear plot). DDT&E funding has been spread using a 60 percent spread function, while production funding was spread at 40 percent, and operations funding is based on a composite spread function.

5.9.2.1.1 Power/Subsystems Module

The estimated cost of the stabilization and attitude control subsystem for this module is as follows:

1972 Dollars in Millions

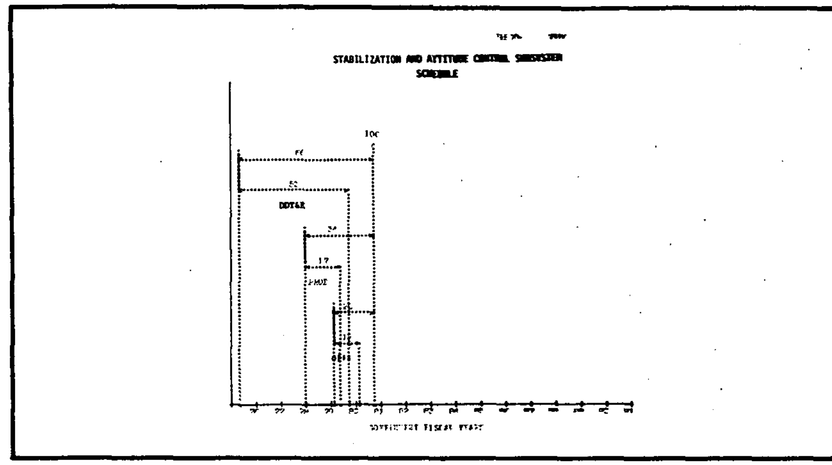
DDT&E	Production	Operations	Total
26	3	4	33

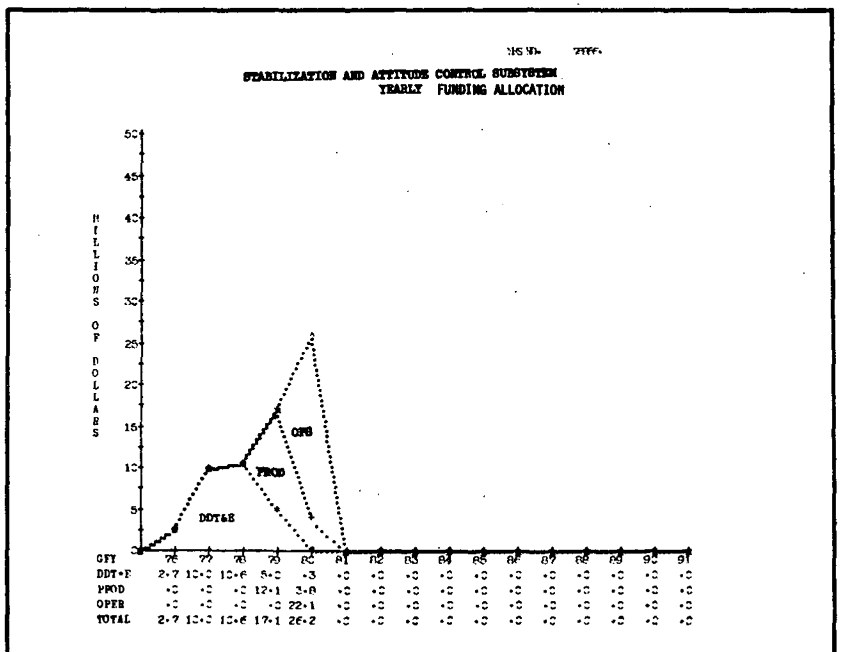
STABILIZATION AND ATTITUDE CONTROL SUBSYSTEM — TECHNICAL DESCRIPTION — WBS 2X75X56

MAJOR SUBASSEMBLY/GROUP	NO. OF EQUIV. UNITS	TOTAL WEIGHT (LB.)	AVE. POWER (WATTS)	CHARACTERISTICS
Attitude Control				
Inertial Reference	.8	18	107	
Horizon Sensor	.8	10	5	
Reaction Control Elect.	1.7	10	22	
Rendezvous Docking				
Docking Reflector	9.0	9	0	
Precision Reference				
Star Tracker	.5	40	2	
Star Sensor	.5	8	4	
Alignment Monitor	.5	15	5	
Control Moment Gyros	5.0	2020	310	

Additional Cost Considerations

Technology - Current	Similarity to Existing Units
Commonality	Complexity
Rate	Accuracy
Power	Reliability
Quantity - Subassemblies/Components	Maintainability





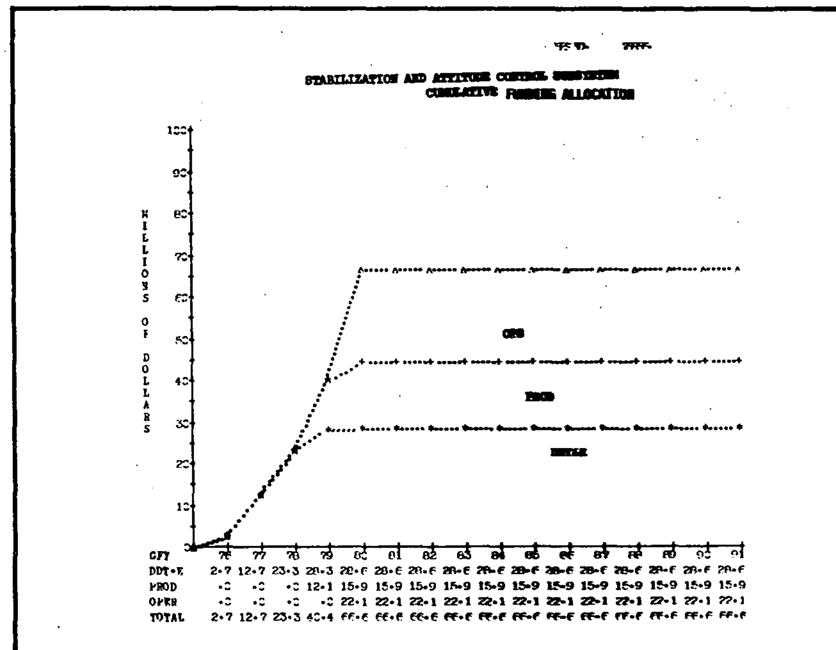


Figure 5-25. Stabilization and Attitude Control Subsystem Summary Chart

5.9.2.1.2 Crew/Operations Module

The estimated cost of the stabilization and attitude control subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
2	13	18	33

5.9.2.1.3 GPL Module

The estimated cost of the stabilization and attitude control subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
0	0	0	1

5.9.3 Schedule

The write-up for this schedule has been combined with that of the guidance and navigation subsystem (Subsection 5.5.3). The schedule for the stabilization and attitude control subsystem is shown in Figure 5-26.

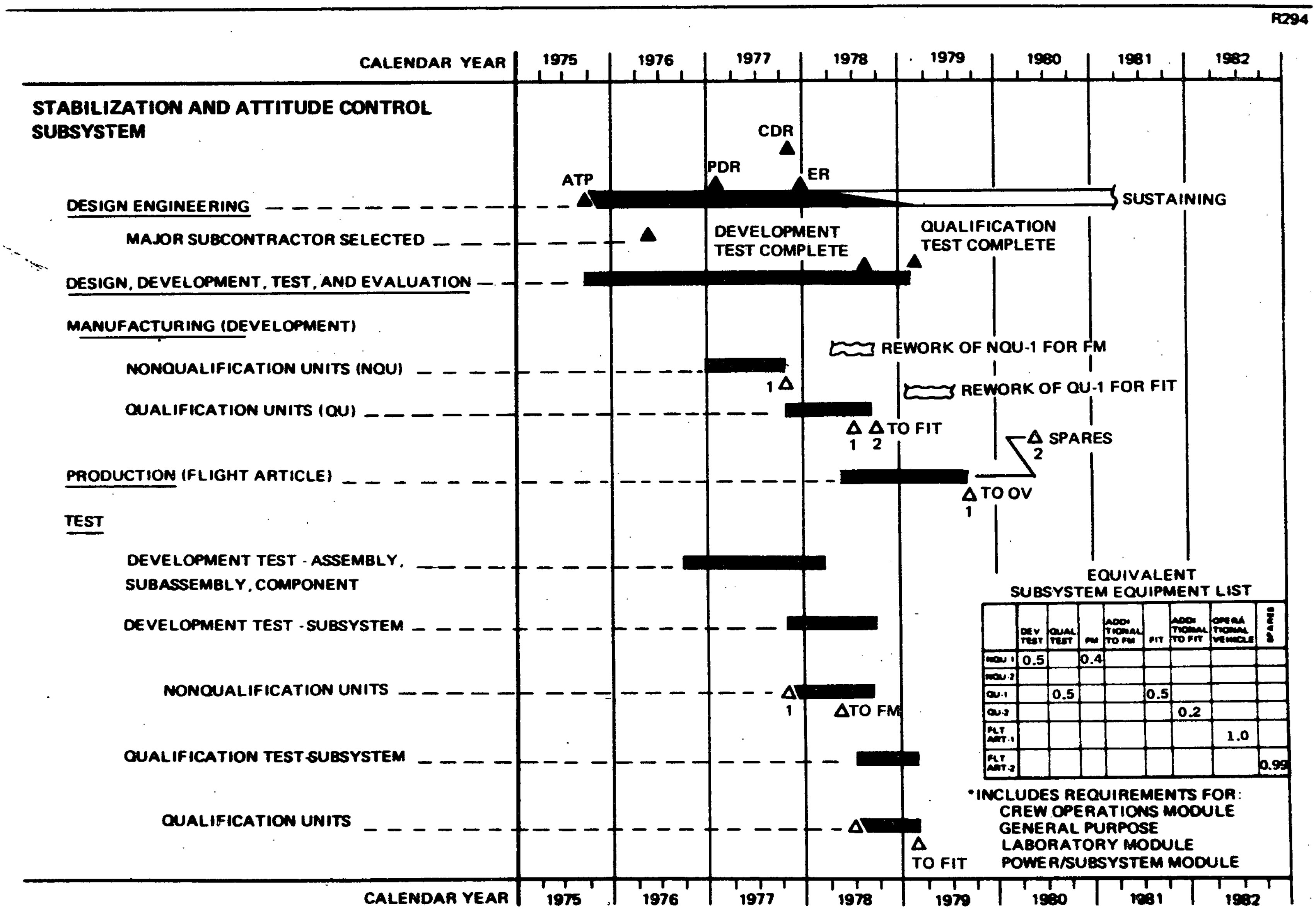


Figure 5-26. Stabilization and Attitude Control Subsystem Schedule (ISS Only)

5.10 ONBOARD CHECKOUT AND FAULT ISOLATION SUBSYSTEM (WBS 2 x 75 x 57)

5.10.1 Summary

The Space Station onboard checkout subsystem (OCS) includes the equipment required for inflight checkout and fault isolation of subsystems and experiments.

It consists primarily of remote data acquisition units, transceivers, data terminals, display control equipment, and independent caution and warning system and some special test equipment. It utilizes the compilation capability of the data management subsystem. To a large extent, this equipment has design commonality or is integrated with other onboard hardware and software.

This subsystem is illustrated in the WBS assembly level breakdown in Figure 5-27.

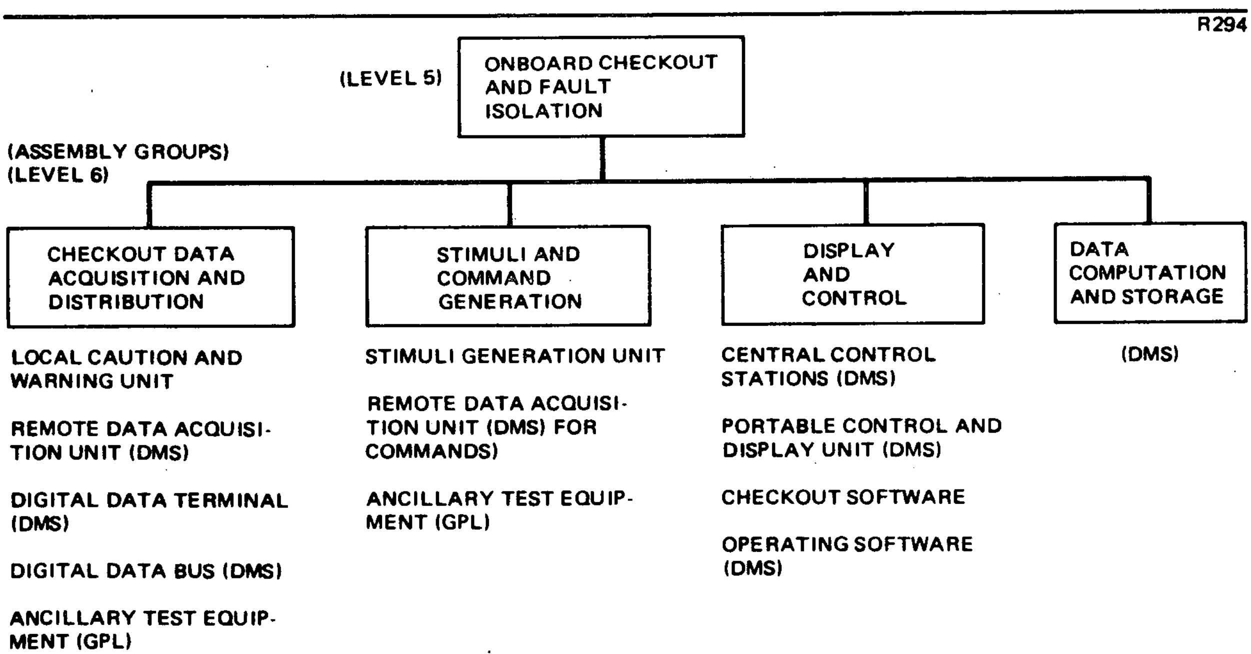


Figure 5-27. Onboard Checkout and Fault Isolation Subsystem Assembly Breakdown

Definition

The task definition for this WBS box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

There are none in addition to those in Section 2. 1. 2.

5. 10. 2 Costs

5. 10. 2. 1 Space Station Modules

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Cost Estimate

The total cost, estimated to be $23 million, is broken down as follows:

DDT&E—It is estimated that the DDT&E effort will cost $16 million, will begin 66 months prior to the milestone launch date of October 1980, and will require 53 months for completion.

Production—It is estimated that the production effort will cost $4 million, will begin 36 months prior to the milestone launch date of October 1980, and will require 15 months for completion.

Operations—It is estimated that the operations effort will cost $3 million, will begin 24 months prior to the milestone launch date of October 1980, and will continue for 18 months.

Funding Distribution

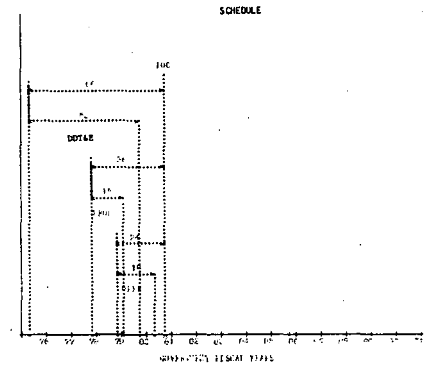
Figure 5-28 is a summary chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government fiscal year (midyear plot). DDT&E funding has been spread using a 60 percent spread function, while production funding was spread at 40 percent, and operations funding is based on a composite spread function.

ONBOARD CHECKOUT AND FAULT ISOLATION SUBSYSTEM — TECHNICAL DESCRIPTION — WBS 2X75X57

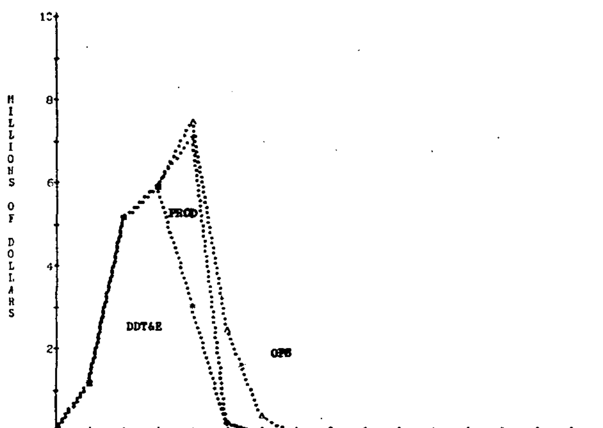
MAJOR SUBASSEMBLY/GROUP	NO. OF EQUIV. UNITS	TOTAL WEIGHT (LB.)	AVE. POWER (WATTS)	CHARACTERISTICS
Data Bus				
Digital Terminals	23	115	460	
Remote Data Acquisition Units	41	38	114	
Command Decoders	1	3	5	
Stimuli Generator Units	13	120	20	
Ancillary Equipment	1	50	20	
Local C/W Unit	17	68	119	

Technology - Current - Dependent upon Data Management Subsystem Capability

ONBOARD CHECKOUT AND FAULT ISOLATION SUBSYSTEM
SCHEDULE

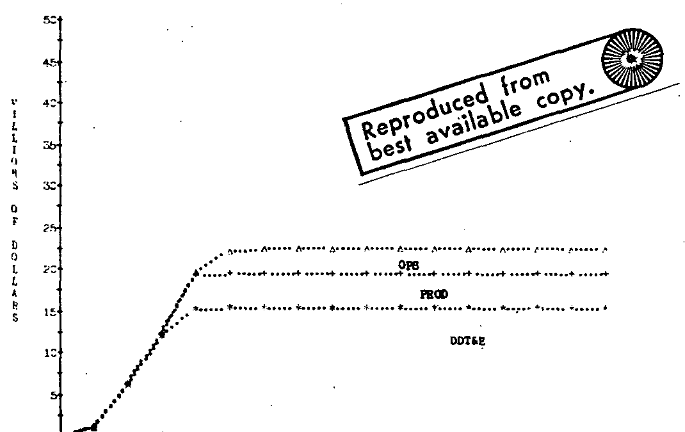


ONBOARD CHECKOUT AND FAULT ISOLATION SUBSYSTEM
YEARLY FUNDING ALLOCATION



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT&E	1.2	5.2	5.9	3.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.0	.0	4.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.4	2.3	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	1.2	5.2	5.9	7.5	2.5	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

ONBOARD CHECKOUT AND FAULT ISOLATION SUBSYSTEM
CUMULATIVE FUNDING ALLOCATION



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT&E	1.2	6.4	12.3	15.3	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
PROD	.0	.0	.0	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
OPER	.0	.0	.0	.4	2.7	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
TOTAL	1.2	6.4	12.3	19.8	22.3	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7

Figure 5-28. Onboard Checkout and Fault Isolation Subsystem Summary Chart

5.10.2.1.1 Power/Subsystems Module

The estimated cost of the onboard checkout and fault isolation subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
5	1	1	7

5.10.2.1.2 Crew/Operations Module

The estimated cost of the onboard checkout and fault isolation subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
5	1	1	7

5.10.2.1.3 GPL Module

The estimated cost of the onboard checkout and fault isolation subsystem for this module is as follows:

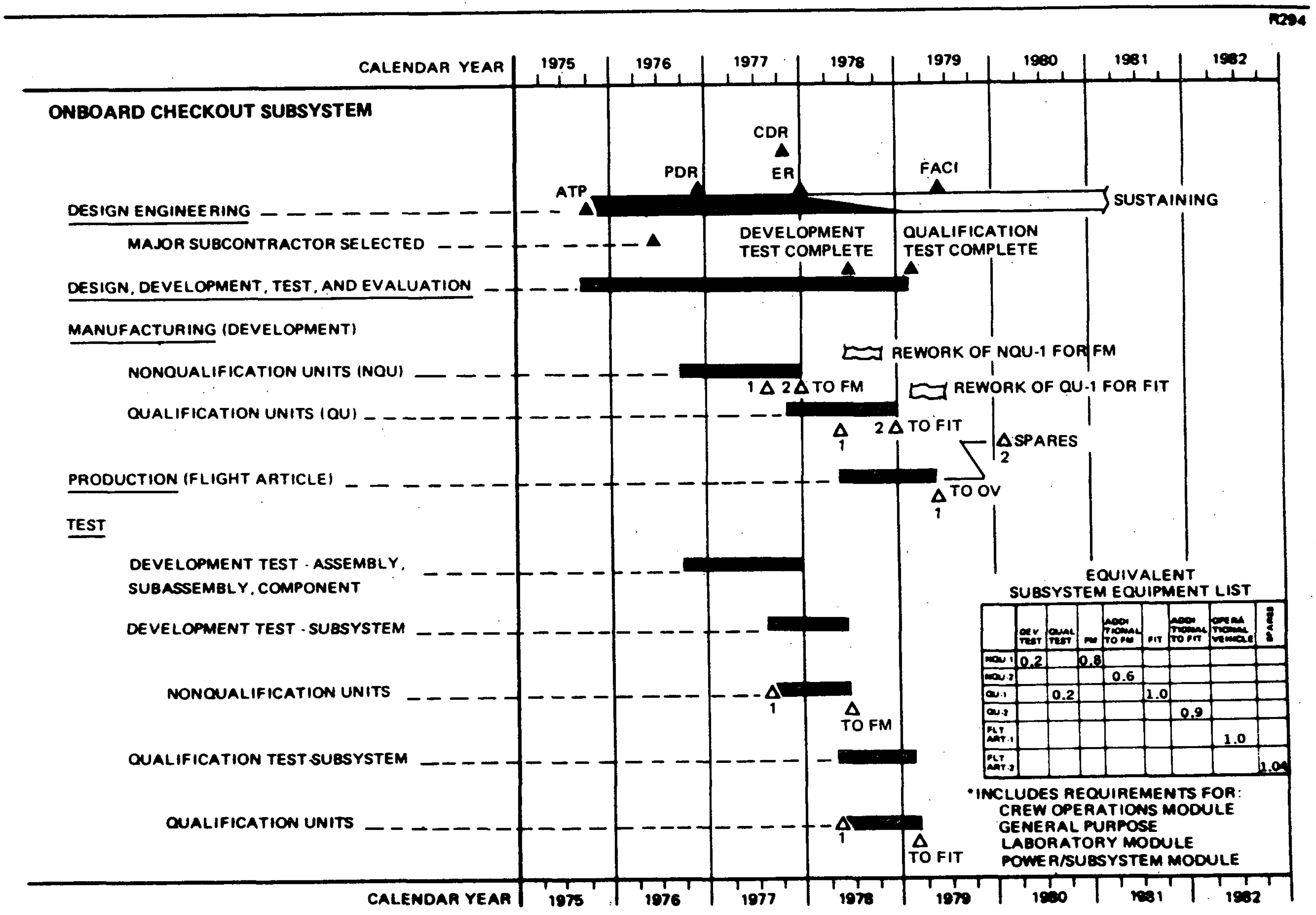
1972 Dollars in Millions

DDT&E	Production	Operations	Total
6	2	1	9

5.10.3 Schedule

The schedule for development of the OCS is shown in Figure 5-29. This schedule identifies equivalent subsystem-level equipment (Table 5-11) and development activities required to design, test, and produce the subsystem. It provides major milestones, key events, and critical actions pertaining to the subsystem.

The OCS design engineering starts at Phase C/D ATP. The major subcontractor ATP occurs 9 months into Phase C/D in order to establish the design requirements and design approach required for PDR. The engineering release for the OCS occurs 27 months after Phase C/D ATP and 5 months



	DEV TEST	QUAL TEST	FM	ADDITIONAL TO FM	FIT	ADDITIONAL TO FIT	OPERATIONAL VEHICLE	SPARES
NQU-1	0.2		0.8					
NQU-2				0.6				
QU-1		0.2			1.0			
QU-2						0.9		
FLT ART-1							1.0	
FLT ART-2								1.0*

Figure 5-29. Onboard Checkout Subsystem Schedule (ISS Only)

Table 5-11

ONBOARD CHECKOUT AND FAULT ISOLATION EQUIVALENT SUBSYSTEM EQUIPMENT LEGEND

	Development Test	Qualification Test	FM	Additional to FM	FIT	Additional to FIT	Operational Vehicle	Spares
NQU-1	0.2		0.8					
NQU-2				0.6				
QU-1		0.2			1.0			
QU-2						0.9		
FA-1							1.0	
FA-2								1.040

before the final Space Station Modules system ER data. The CDR occurs 2 months before ER. FACI is performed at the time of delivery of the flight hardware in June 1979. The DDT&E begins with Phase C/D ATP and ends at qualification test completion in April 1978.

The manufacturing time span begins with the nonoperational units in October 1976 and is completed with the manufacture of the production units for spares in January 1980.

Two nonqualification units are produced. One is utilized in development testing (11-month duration) of the subsystem. At the completion of the test, it is then shipped to the functional model (FM). The second nonqualification unit is shipped directly to the FM upon completion of manufacture. One qualification unit is produced for the qualification testing (10-month duration). At the completion of the qualification test, it is shipped to the FIT for integration and testing. A second unit (0.9 equivalent) is produced and shipped directly to the FIT 3 months before the first unit. Additional testing is performed early in the development phase at the component, subassembly, and assembly levels.

The OCS is subjected to an orderly sequence of compatibility development tests conducted using the functional model (FM). The FM is the primary engineering tool used for system-level hardware and software development. The testing culminates in the establishment of an operational checkout system which is then used to support other FM development testing, integration, and checkout software development activities.

Key to the development of the OCS is its integration with the DMS. The DMS capabilities for data acquisition and distribution, computation, data storage, displays and controls, command generation, and operating system software must be operational prior to any meaningful OCS development testing.

Following the establishment of the required DMS capabilities, other elements unique to the OCS are added to the FM. These elements include hardware required for stimuli generation and for caution and warning functions. Interfaces of all elements within the OCS, as well as OCS/DMS self-test software, are then verified.

Hardware and software interfaces with the GSE are established and verified. The OCS interface with other ISS subsystems is accomplished in an orderly sequence, adding one subsystem interface at a time. Initial tests are conducted to verify compatibility between the OCS, subsystems under test, GSE, procedures, and the attendant software programs. Where interfacing subsystems are not available, either an interface substitute is provided or the functions are simulated using software. Compatibility development testing with the FM is then continued to develop integrated subsystem checkout software and the software required for acceptance testing, prelaunch checkout, and the mission.

As integral experiments are made available to the FM, these are also interfaced with the OCS and development tests conducted. Once the integrity of ISS subsystems is established, the OCS experiment interface and checkout software development can occur in parallel with other FM activities.

5.11 EXPERIMENT SUPPORT EQUIPMENT SUBSYSTEM (WBS 2 x 75 x 39)

5.11.1 Summary

The experiment support equipment subsystem provides the Space Station Modules system with a specific general purpose capability based on:

1. Requirements to support the defined experiment program and undefined experiments to be conducted during the 5 years following ISS activation.
2. Requirements to support the operation of the Space Station and its subsystems. These facilities will include shops and labs to repair, disassemble and assemble and calibrate subsystem equipment.
3. Requirements to support the separately launched experiment modules.

The equipment definition is based on identified requirements, but does not necessarily satisfy all of them. When actual support requirements develop, the support can be provided by carry-on equipment, etc. Experiment support equipment cost baseline includes only the specific capability defined.

The above experiment support equipment is not unique to an individual FPE but supports multiple FPE's as well as Space Station Modules support requirements. This support equipment is not limited to integral experiments. This subsystem is illustrated in the WBS assembly level breakdown in figure 5-30.

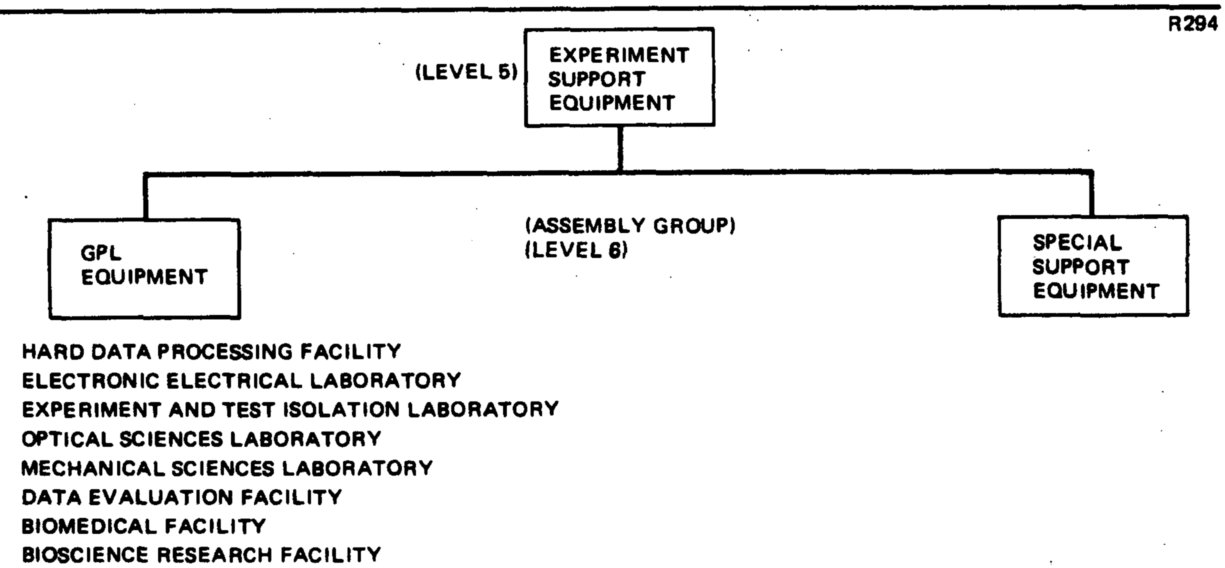


Figure 5-30. Experiment Support Equipment Subsystem Assembly Breakdown

Definition

The task definition of this WBS box in contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

There are none in addition to those in Section 2.1.2.

5.11.2 Costs

5.11.2.1 Space Station Modules

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Cost Estimate

The total cost, estimated to be $30 million, is broken down as follows:

DDT&E—It is estimated that the DDT&E effort will cost $15 million, will begin 66 months prior to the milestone launch rate of October 1980, and will require 50 months for completion.

Production—It is estimated that the production effort will cost $8 million, will begin 37 months prior to the milestone launch date of October 1980, and will require 13 months for completion.

Operations—It is estimated that the operations effort will cost $7 million, will begin 25 months prior to the milestone launch date of October 1980, and will continue for 16 months.

Funding Distribution

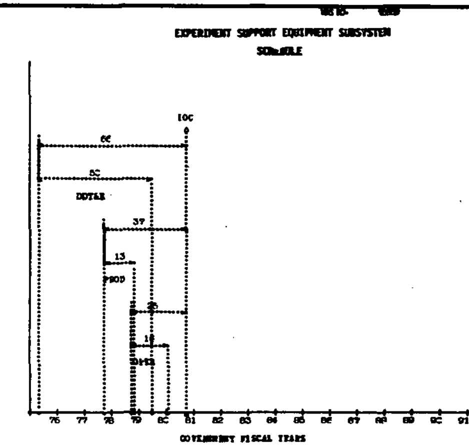
Figure 5-31 is a summary chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government fiscal year (midyear plot). DDT&E funding has been spread using a 60 percent spread function, while production funding was spread at 40 percent, and operations funding is based on a composite spread function.

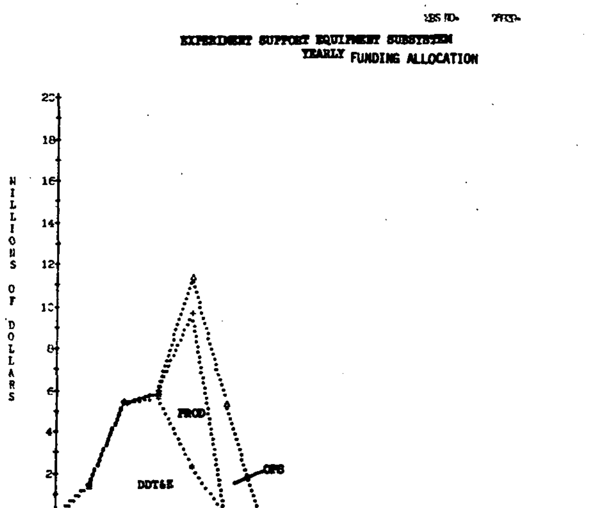
EXPERIMENT SUPPORT EQUIPMENT SUBSYSTEM — TECHNICAL DESCRIPTION — WBS 2X75X39

MAJOR SUBASSEMBLY/GROUP	TOTAL WEIGHT (LB.)	VOLUME (CU.FT.)	DENSITY ($LB./FT^3$)	CHARACTERISTICS
Hard Data Processing Facility	2054	267.2	7.68	
Electronic/Electrical Lab.	516	122.9	4.20	
Experiment and Test Isolation Laboratory	403	120.1	3.35	
Optical Sciences Laboratory	427	101.9	4.18	
Mechanical Laboratory	584	111.9	5.22	
Biomedical/Bioscience Lab.	406	98.7	4.10	
Data Evaluation Facility	797	111.2	7.16	
TOTAL	5187	933.8	5.55	

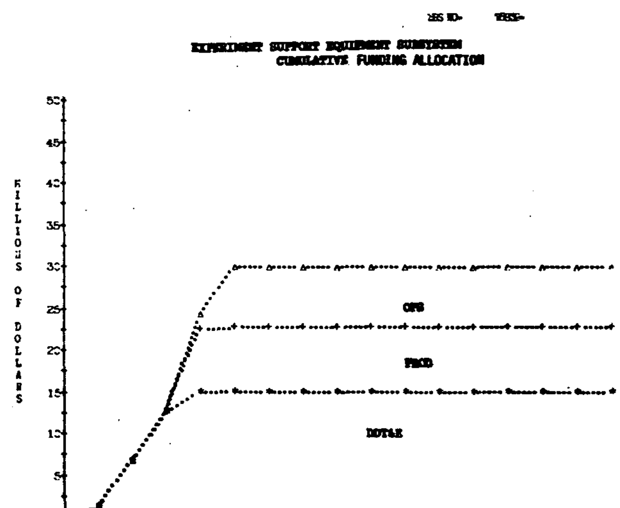
Additional Cost Considerations

Technology - Generally Current	Quantity - Subassemblies/Components
Function	Commonality
Size/Material/Fabrication Method	Complexity
Similarity to Existing Units	Reliability
Maintainability	Multiple Usage





GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	1.5	5.5	5.7	2.4	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.0	.3	7.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	1.0	5.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	1.5	5.5	6.0	11.5	5.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	1.5	7.0	12.7	15.1	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2
PROD	.0	.0	.3	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
OPER	.0	.0	.0	1.8	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
TOTAL	1.5	7.0	13.0	24.5	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

Figure 5-31. Experiment Support Equipment Subsystem Summary Chart

5.11.2.1.1 Power/Subsystems Module

The estimated cost of the experiment support equipment subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
0	0	0	0

5.11.2.1.2 Crew/Operations Module

The estimated cost of the experiment support equipment subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
0	0	0	0

5.11.2.1.3 GPL Module

The estimated cost of the experiment support equipment subsystem for this module is as follows:

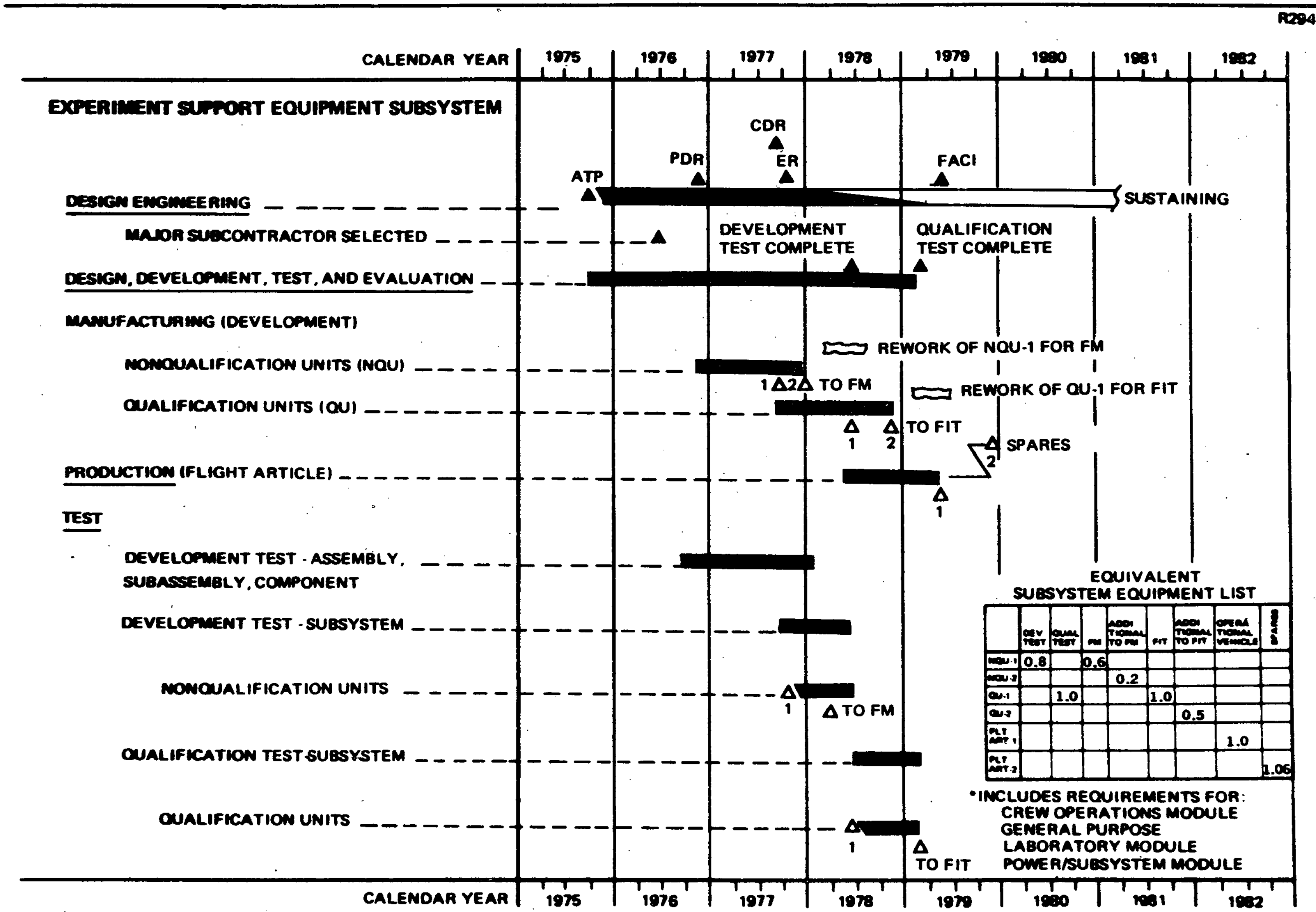
1972 Dollars in Millions

DDT&E	Production	Operations	Total
15	8	7	30

5.11.3 Schedule

The schedule for the Space Station module experiment support equipment subsystem is shown in Figure 5-32. This schedule identifies equivalent subsystem level equipment (Table 5-12) and development activities required to design, test, and produce the subsystem. The schedule provides major milestones, key events, and critical actions related to the subsystem.

The experiment support equipment subsystem design engineering starts at Phase C/D ATP. Major subcontractor ATP occurs 9 months into Phase C/D to establish the design requirements and design approach required for PDR. The ER for the GPL subsystem occurs 25 months after Phase C/D ATP and 5 months before the Space Station Modules system ER final date. The CDR



	DEV TEST	QUAL TEST	FM	ADDITIONAL TO FM	FIT	ADDITIONAL TO FIT	OPERATIONAL VEHICLE	SPARES
NQU-1	0.8		0.6					
NQU-2				0.2				
QU-1		1.0			1.0			
QU-2						0.5		
FLT ART 1							1.0	
FLT ART 2								1.06

Figure 5-32. Experiment Support Equipment Subsystem Schedule (ISS Only)

Table 5-12

EXPERIMENT SUPPORT EQUIPMENT EQUIVALENT SUBSYSTEM EQUIPMENT LEGEND

	Development Test	Qualification Test	FM	Additional to FM	FIT	Additional to FIT	Operational Vehicle	Spares
NQU-1	0.8		0.6					
NQU-2				0.2				
QU-1		1.0			1.0			
QU-2						0.5		
FA-1							1.0	
FA-2								1.061

occurs 2 months before ER. FACI is performed at the time of delivery of the flight hardware in May 1979. DDT&E begins with Phase C/D design and ends at qualification test completion in March 1979.

The manufacturing time span begins with the nonoperational units in December 1976 and is completed with the manufacture of the qualification units for spares in December 1979. One nonqualification unit is produced and used in development testing (8-months duration) of the subsystem. Three months prior to the completion of the test, 40 percent of the unit is shipped to the functional model. A second nonqualification unit is shipped directly to the FM upon completion of manufacture. One qualification unit is produced for the qualification testing (8-month duration). At the completion of the qualification test, it is shipped to the flight integration tool (FIT) for integration and testing. A second qualification unit (0.5 equivalent) is shipped directly to the FIT upon completion of manufacture.

The primary critical issue is identification and scheduling of the design of the experiments and operational equipment. These must be sufficiently timely so that the proper items of equipment can be included in the SSM's launches, the equipment can be modified as necessary for functional operation in zero-g conditions, and the operating personnel can be trained to a level of proficiency in mockups to ensure adequate performance in space. This is complicated because the design requirements of the Space Station Modules system and its subsystems must be approved as a baseline, defining the resources which will be available to the experiment contractors. To meet Space Station Modules system design schedules, much of ESE will be based on preliminary experiment design. The problem is mitigated by ESE definition which states that it will contain state-of-the-art equipment. Special support items will remain within the responsibility of the experiments requiring their use as to design, development, operator training, etc.

Management of the tie-in between the Space Station Modules system ESE subsystem design and that of the individual experiments will be more critical and complex than experienced on previous programs. Experiment contractors must report ESE support requirements early in their design cycle; these must be formalized at the time of experiment PDR. Under the presently identified experiment program, there have been no critical issues identified.

5.12 INSTALLATION AND INTEGRATION SUBSYSTEM (WBS 2 x 75 x 01)

5.12.1 Summary

The installation and integration subsystem provides the following services during the production (recurring) phase only:

A. Manufacturing
1. Provide all material and miscellaneous fabrication for one flight article system assembly (from complete subsystem).
2. Assembly of one flight article (Space Station Modules).
3. Provide quality assurance, production control, calibration, and other support effort for assembly.

Definition

The task definition of this WBS box is contained in Appendix A.

Cost Assumptions, Ground Rules and Rationale

There are none in addition to those in Section 2.1.2.

5.12.2 Costs

5.12.2.1 Space Station Modules

Cost Methodology

The estimated costs have been developed from summations of cost estimates at subordinate levels. The subordinate cost estimates were developed at one or more levels below that being reported. The costs reported at this level include the cost of integrating the elements at the subordinate levels.

Cost Estimate

The total cost, estimated to be $67 million, is production cost.

It is estimated that the production effort will begin 43 months prior to the milestone launch date of October 1980, and will require 39 months for completion.

Funding Distribution

Figure 5-33 is a summary chart which highlights the relationships of the cost estimates to technical characteristics and schedules. It also presents an overview of the funding allocations, both yearly and cumulatively by Government fiscal year (midyear plot). Production funding was spread at 45 percent.

5.12.2.1.1 Power/Subsystems Module

The estimated cost of the installation and integration subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
0	25	0	25

5.12.2.1.2 Crew/Operations Module

The estimated cost of the installation and integration subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
0	24	0	24

5.12.2.1.3 GPL Module

The estimated cost of the installation and integration subsystem for this module is as follows:

1972 Dollars in Millions

DDT&E	Production	Operations	Total
0	18	0	18

5.12.3 Schedule (See Space Station Modules system schedule)

This subsystem provides for production of the following:

A. All material and miscellaneous fabrication for one flight system assembly (from complete subsystems).

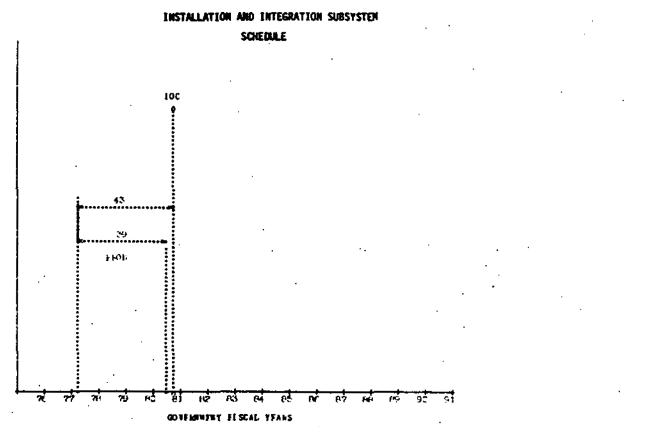
B. Assembly of one flight article (Space Station module).

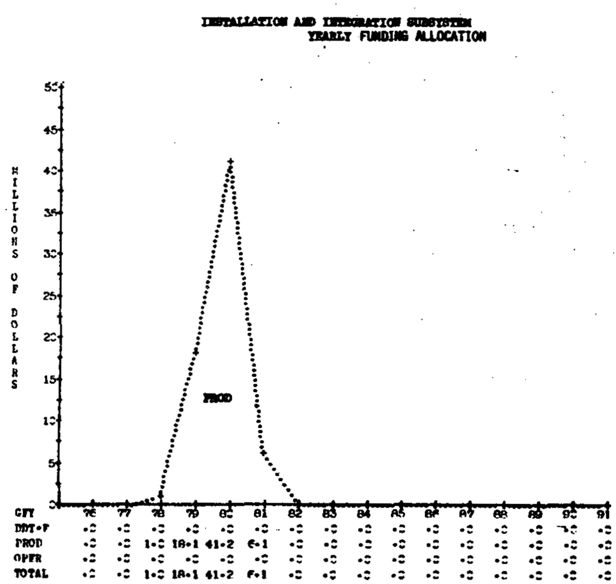
C. Quality assurance, production control, calibration, and other support effort.

INSTALLATION AND INTEGRATION SUBSYSTEM	TECHNICAL DESCRIPTION	WBS 2X75X01
MAJOR SUBASSEMBLY/GROUP	CHARACTERISTICS	
Production	Includes material and miscellaneous fabrication of one flight article assembly from complete subsystems. Includes quality assurance, production control, calibration, and other support effort for assembly.	

Additional Cost Considerations

Size	Commonality
Materials	Fabrication/Assembly Methods
Quantity - Subsystems	Quantity - Flight Articles
Weight	Tooling Requirements
Test Philosophy	GSE Philosophy
Maintainability	Reliability





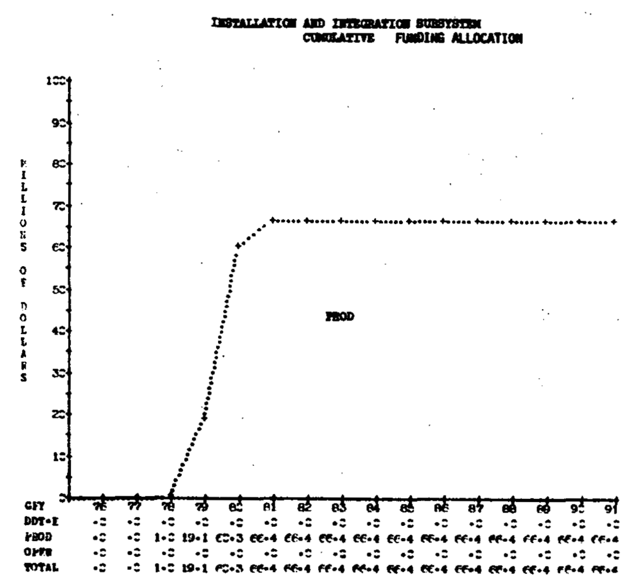


Figure 5-33. Installation and Integration Subsystem Summary Chart

SPACE STATION PROGRAM

(MODULAR)

COST ESTIMATING GROUNDRULES

APPENDIX A

TASK DESCRIPTIONS

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WORK DESCRIPTION

SPACE STATION PROGRAM

CONTENTS

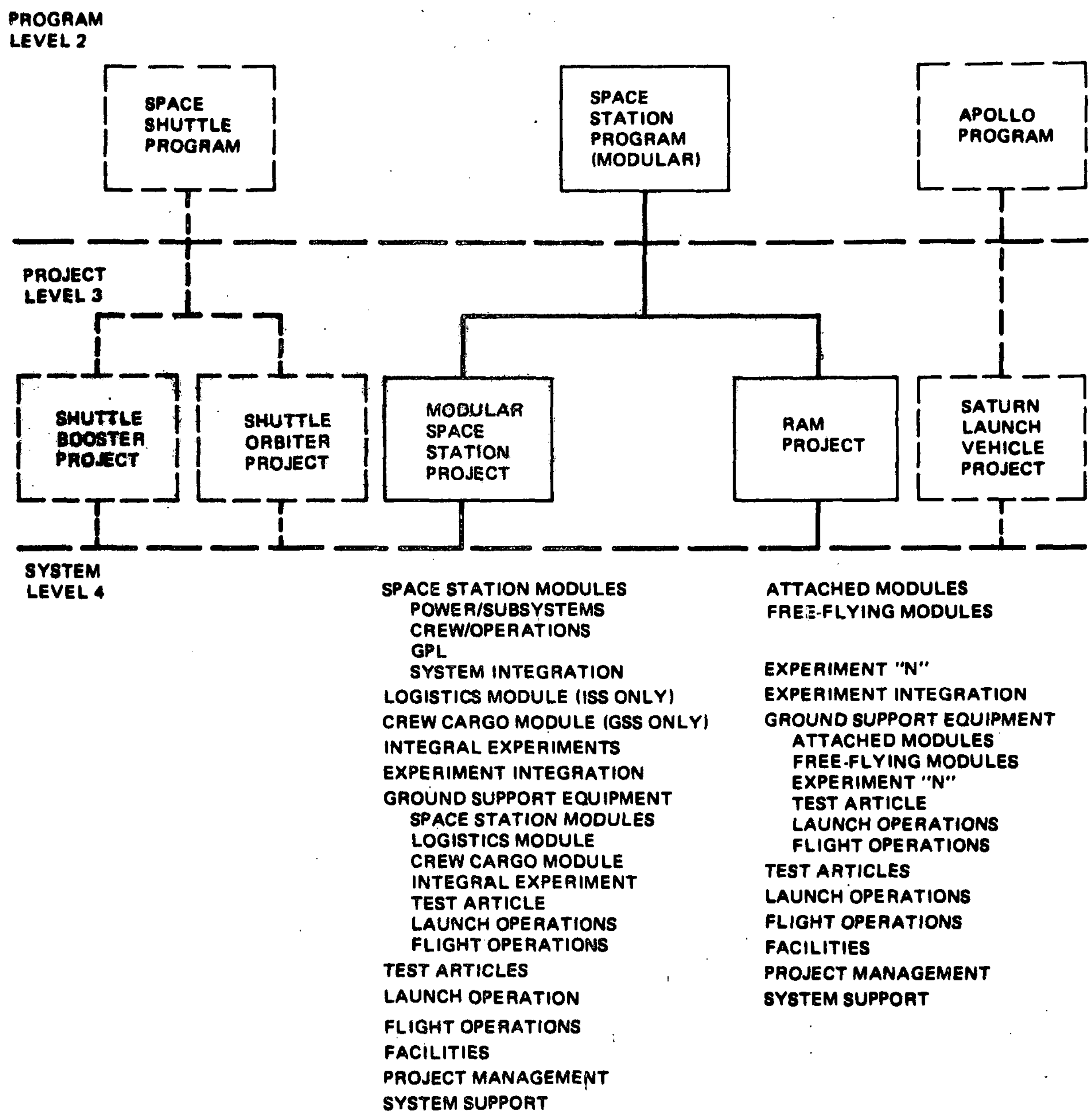

Figure A-1. Work Breakdown Structure for Space Station Program (Modular)

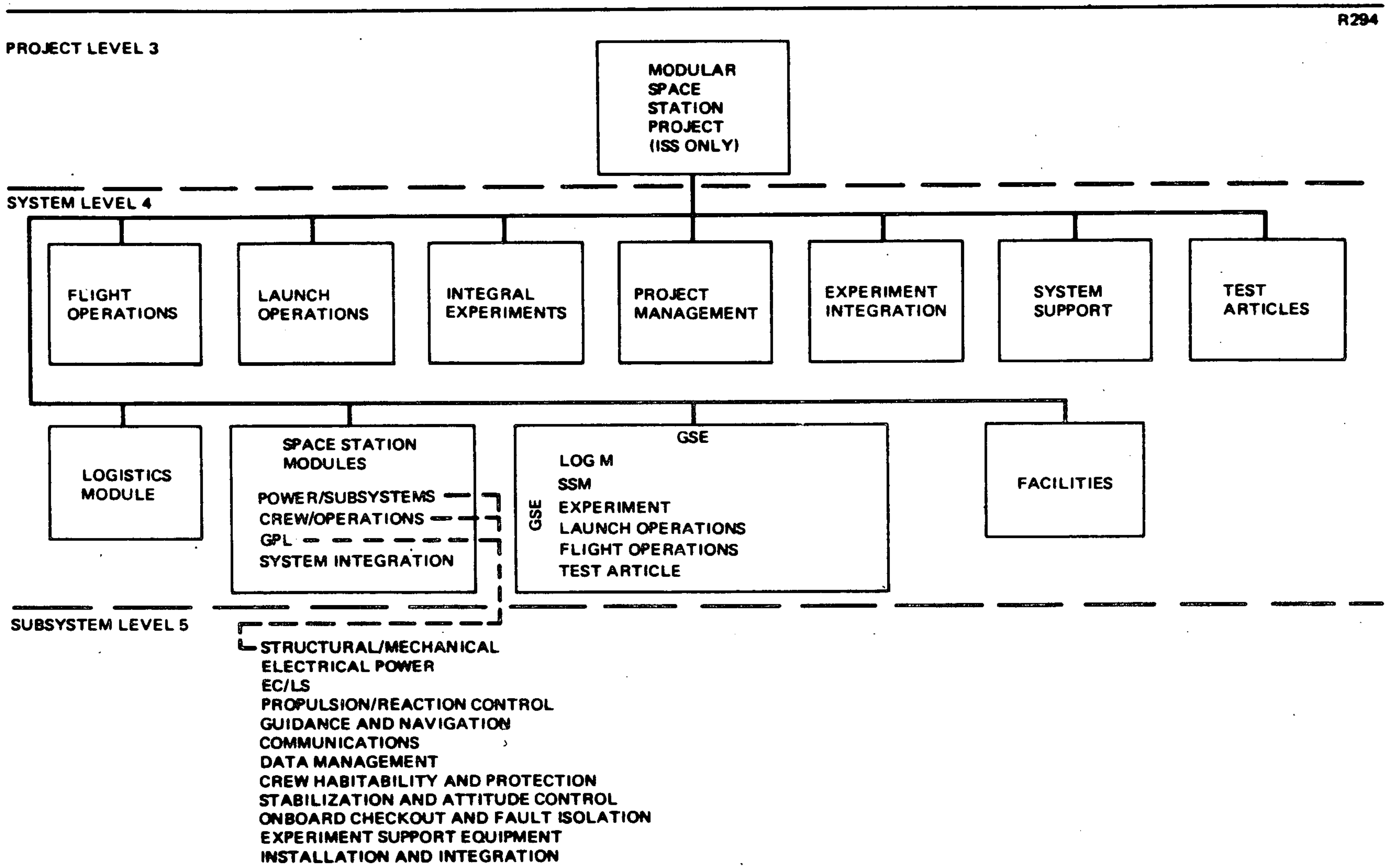

Figure A-2. Work Breakdown Structure for Space Station Project (ISS Phase)

SPACE STATION PROGRAM (MODULAR)

The Space Station Program consists of all effort defined in the lower level boxes of the Space Station Study WBS. Cost of the following items has been excluded by NASA direction.

- NASA program management and system support
- Space Station program portion and use of the Ground Network and synchronous satellite communication institutional base facilities.
- Crew training and development, operations and maintenance of non-flight hardware (computers, trainers, simulators, associated software, etc.) to be used for crew training, simulation and for crew problem evaluation.

The summation of the lower level boxes of the Space Station Study WBS is reported in the program cost estimate supplied at WBS Level 2. Contractor system support and project management are included in lower level WBS boxes. The Space Station Program consists of two phases. The Initial Space Station (ISS) phase is used to describe the first five year operational phase and the necessary DDTE (including experiments, Space Station Project and RAM Project) to achieve that capability. GSS (Growth Space Station) phase is used to describe the second five year operational phase and the necessary additional DDTE to achieve that capability. It is assumed for lower level costing purposes that the NASA system support and program management encompass the following:

SYSTEM SUPPORT

System Support, at WBS Level 2 includes all NASA technical, scientific and engineering effort for support of the Space Station Program. It consists of technical effort for system engineering and technical direction of the program. The following tasks are included:

Design, Development, Test and Engineering

Provide overall technical direction, interface resolution between projects and technical support.

Production

Continued technical direction, verification of compliance with requirements, interface resolution and technical support.

Operations

Technical direction of Space Station and RAM operations, resolution of experiment interfaces, review of experiment data and technical support.

PROGRAM MANAGEMENT

Program Management, at WBS Level 2, consists of all non-technical NASA management for the Space Station Program. These activities continue through DDT&E, Production, and Operations phases. The following types of effort are included:

Program Planning and Control
Program Reviews and Direction
Contract and Financial Management
Coordination with other government agencies

The above items are not costed in the Space Station Program costs but are identified so that lower level boxes will not duplicate these functions.

SPACE SHUTTLE OPERATIONS (ISS & GSS) (NASA FURNISHED COST DATA)

Definition

The Space Shuttle operations effort included in the Space Station Study is the launch and flight operations cost for all flights in support of the Space Station and RAM Projects. These costs were supplied by NASA and are currently identified as $\$4.5 \times 10^6$/flight chargeable to the Space Station Program. This is based on a fully reusable Shuttle.

Tasks

Launch and Flight Operations (Operations)—the operations cost per flight is based on a maximum of 12 launches per year. Refurbishment, launch operations, propellants and spares are included. All launches are assumed to be from KSC.

Project Management, System Support and amortized production costs are excluded per NASA request.

The current 10-year Space Station baseline (534G) requires a total of 114 shuttle launches at an expense of $513 million.

SPACE STATION PROJECT (ISS & GSS)

The Space Station Project includes the following flight systems:

Space Station Modules (ISS-Power/Subsystems No. 1, Crew/Operations No. 1, GPL; GSS-Crew/Operations No. 2, Power/Subsystems No. 2)

Integral Experiments

Logistics Modules (ISS only)

Crew/Cargo Modules (GSS only)

The effort in this project includes all DDT&E, Production and Operations for the flight systems plus related GSE, facilities and test articles. Also included are launch and flight operations, management and support tasks.

NASA Program support (Program Management and System Support) and a portion of the NASA operations support (crew training, ground network and synchronous satellite operations) costs are not included in the Space Station Project costs per NASA direction.

The balance of the NASA operations support (ground crew training, etc.) are identified under the launch and flight operations WBS boxes but the costs for these tasks are excluded per NASA direction.

SPACE STATION MODULES (ISS)

Definition

The Space Station Modules are the major system of the Modular Space Station Project. Space Station Modules for the ISS phase consists of Power/ Subsystems, Crew Operations and General Purpose Laboratory modules as well as system integration (system support, non-recurring test operations, module acceptance testing). Excluded are the additional modules and modification equipment required to provide the GSS capability. System support, test operations and acceptance testing effort which is common to the modules are included in this WBS box at Level 4 as systems integration. This includes system design and development, system testing and acceptance.

All effort for design, development, test and manufacture of the individual subsystems and system level flight article installation and assembly is done in the subsystem WBS boxes at level 5.

All design tasks include initial design only. Sustaining Engineering is covered in the System Support WBS box.

Excluded from this WBS are the hardware costs for the Functional Model (FM) and the Flight Integration tool (FIT) which are covered in the Test Article "N" WBS box. However, design effort and test operations using these test articles are included here.

All work is Contractor effort in the DDT&E and Production categories.

Work Breakdown

Work Included in this WBS box at Level 4 includes the following:

A. Design, Development, Test and Engineering (non-recurring)

1. Initial Engineering

   a. Provide system level design through completion of system engineering release.

   b. Provide support to System Support activities, primarily in interface design (I&SR/ICD's).

c. Prepare system level development test requirements, procedures, simulation programs, analysis and reports related to integration testing of two or more subsystems (hardware and software). EMI testing is included.

d. Prepare Space Station modules operating procedures.

e. Provide Test Article "N" Design. These are derivatives of the Space Station design and are the Functional Model and Flight Integration tool. These items are described in the Test Article "N" WBS box. The design task is preparation of test article-peculiar FIT arrangement and interconnect drawings and Software programs.

f. Design of mockups (non-deliverable).

2. <u>Test Operations</u>

a. Conduct Space Station System integration testing, software development and operating procedure development on the Functional Model and FIT including GSE support.

b. Fabrication and development of design mockups.

3. <u>Production Planning and Tooling</u>

a. Provide Space Station manufacturing engineering for test Article "N" and flight article assembly.

b. Design and fabricate tooling (assembly fixtures) and production aids.

c. Provide quality assurance and other production support effort for system tooling.

d. Provide system production planning.

B. <u>Production (Recurring)</u>

1. <u>Manufacturing</u>

a. Perform pre-acceptance checkout and acceptance tests.

<u>SPACE STATION MODULES SUBSYSTEMS (ISS)</u>

Each of the Space Station's 11 subsystems are described briefly in the following subsystem WBS boxes. For greater detail, refer to the Baseline Program Document.

Task Summary, Work Breakdown and other Subsystem information which is common to all is provided for the Stabilization and Attitude Control Subsystem only and is applicable to all of the subsystems. The quantities of subsystem test articles vary and are tabulated in the table on the following page.

SPACE STATION MODULES SUBSYSTEMS
EQUIVALENT DEVELOPMENT QUANTITY
(Shipsets)[1]

WBS	Subsystem	Development Test	Qualification Test
8x24	Electrical Power	0.8	1.2
8x05	EC/LS	0.5	0.4
8x59	Crew Habitability and Protection	0.4	0.4
8x23	Propulsion/Reaction Control	0.5	0.5
8x47	Data Management	0.4	0.4
8x56	Stabilization and Attitude Control	0.5	0.5
8x46	Guidance and Navigation	1.0	1 2
8x07	Communications	0.5	0.6
8x57	Onboard Checkout and Fault Isolation	0.2	0.2
8x02	Structural/Mechanical	0.2	0.8
8x39	Experiment Support Equipment	0.8	1.0

Note:

(1) Shipset is Space Station Modules equivalent (3 modules worth).

3

SPACE STATION MODULES TEST ARTICLE EQUIVALENT SUBSYSTEMS QUANTITY

(Shipsets)[4]

WBS	Subsystem	Test Article Requirements (See Notes 1 and 2): FM	Add to FM	FIT	Add to FIT	Test Article "N" Manufacturing Requirements
8x24	Electrical Power	0. 7	0. 2	0. 8	0. 2	0. 4
8x50	EC/LS	0. 2	0	1. 0	0. 8	0. 8
8x59	Crew Habitability and Protection	0. 1	0	0. 9	0. 7	0. 7
8x23	Propulsion/Reaction Control	0. 2	0	0. 9	0. 6	0. 6
8x47	Data Management	0. 9	0. 7	1. 0	0. 8	1. 5
8x56	Stabilization and Attitude Control	0. 4	0	0. 5	0. 2	0. 2
8x46	Guidance and Navigation	0. 6	0. 1	0. 4	0	0. 1
8x07	Communications	0. 6	0. 2	0. 5	0. 2	0. 4
8x57	Onboard Checkout and Fault Isolation	0. 8	0. 6	1. 0	0. 9	1. 5
8x02	Structural/Mechanical	0	0	0. 9	0. 1	0. 1
8x39	Experiment Support Equipment	0. 6	0. 2	1. 0	0. 5	0. 7

Notes:
(1) Subsystem Functional Development test hardware satisfies functional Model Requirements except for additions noted.
(2) Subsystem Functional Qualification Test hardware satisfies FIT Requirements except for additions noted.
(3) Test Article Manufacturing is any additional subsystem equipment not furnished from test hardware. Manufacturing tasks are in test article "N" WBS.
(4) Shipset is Space Station Modules equivalent (3 modules worth).

WBS 75x56

STABILIZATION AND ATTITUDE CONTROL SUBSYSTEM

Description

The stabilization and Attitude Control System functions to:

A. Generate attitude reference information for attitude control, experiments, communications, and guidance and navigation.

B. Provide all attitude capability.

C. Generate commands to reaction jets for attitude and translation control.

D. Maintain station orientation, nominally trimmed Horizontal (Y).

It is composed of attitude and rate sensors; electronics for sensor, computer, experiments, and reaction jet interfaces; display and control elements; and control moment gyros. It utilizes the computation capability of the Data Management Subsystem.

Task Summary

All effort directly associated with the Stabilization and Attitude Control Subsystem prior to integration of the subsystem with other subsystems, exclusive of sustaining engineering. Included are design, development and production of subsystem level STE for development qualification and acceptance testing. All costs are considered to be contractor/subcontractor costs.

Work Breakdown

A. Design, Development, Test and Engineering

1. Initial Engineering

a. Conduct subsystem design analysis

b. Provide preliminary subsystem design

c. Detail subsystem design through engineering release

d. Prepare subsystem development test requirements, procedures, analysis and reports related to development testing of components or assemblies of the subsystem and integration testing at the subsystem level. This includes subsystem computer program development

e. Prepare subsystem qualification test requirements, procedures, analysis and reports related to qualification testing of components or assemblies of the subsystem

2. Test Operations
   a. Manufacture test specimens for subsystem development and qualification tests.
   b. Conduct subsystem development and qualification tests (see 1 (d) and (e) above)

3. Production Planning and Tooling
   a. Provide subsystem manufacturing engineering
   b. Design and fabricate tooling, STE, and production aids
   c. Provide quality assurance and other production effort for fabrication of subsystem tooling
   d. Provide subsystem production planning

B. Production

1. Manufacturing
   a. Provide all material for one flight article subsystem manufacture
   b. Fabricate, assemble and acceptance test one flight article subsystem, including assemblies and components
   c. Provide quality assurance, production control, calibration and other support effort for subsystem production operations (one flight article)
   d. Provide spares for in-plant operations and launch support

C. Operations

a. Provide spares for flight operations.

NOTE: NOT included in this WBS are:

1. Sustaining Engineering (included in System Support)
2. Production of Equipment for Test Article "N" and refurbishment of development and qualification test units
3. System Design

WBS 75x46

GUIDANCE AND NAVIGATION SUBSYSTEM

The guidance and navigation (G/N) subsystem provides station navigational information to be used by experiments, logistics vehicles, experiment modules, etc., and generates guidance commands for orbit keeping and maneuvers. The G/N equipment consists of position and velocity sensors, electronics for sensors and computer interfaces, and display and control elements.

WBS 75x59

CREW HABITABILITY AND PROTECTION SUBSYSTEM

This subsystem provides the facilities and equipment for the crew housing and living. It includes the equipment and facilities for recreation, exercise, lighting and dining, hygiene, and medical care, food, food storage, radiation and meteoroid protection, damage control and safety, crew living and sleeping quarters, and space suits.

WBS 75x23

PROPULSION SUBSYSTEM

This subsystem provides the thrust impulse required to maneuver and position the Space Station in orbit and Station P/RCS is comprised of a high-thrust bi-propellant system and a low-thrust resistojet system. The high-thrust system provides the final orbit adjustment, maneuvers, scheduled disturbances and backup attitude control. The low thrust system will provide the orbit keeping and CMG desaturation functions.

WBS 75x47

DATA MANAGEMENT SUBSYSTEM

The data management subsystem consists of all the necessary equipment to transfer, store, and process data to and from users and subsystems. It is a modularized multiprocessor specifically consisting of processors, memory storage units, switching units, peripheral devices, data adapters, coders, decoders, time synchronous generator, film scanners and reducers, analog tape storage, search and control equipment, signal conditioning and demodulation equipment, and entertainment units.

WBS 75x07

COMMUNICATIONS SUBSYSTEM

The Space Station Communications Subsystem provides:

A. Space Station/Ground Communications
B. Space Station/Shuttle Communications
C. Space Station/RAM Communications

It consists of antennas, amplifiers, receivers, transmitters with appropriate switching and multiplexing units, TV cameras, audio control, etc. center.

WBS 75x57

ONBOARD CHECKOUT AND FAULT ISOLATION SUBSYSTEM

The Space Station Onboard Checkout Subsystem includes the equipment required for in-flight checkout and fault isolation of subsystems and experiments.

It consists primarily of remote data acquisition units, transmitter/receivers, data terminals, display control equipment, and independent caution and warning system and some special test equipment. It utilizes the compilation capability of the Data Management Subsystem.

NOTE: To a large extent this equipment has design commonality or is integrated with other onboard hardware and software.

WBS 75x24

ELECTRICAL POWER SUBSYSTEM

The Electrical Power Subsystem includes a solar array power source, deployment and orientation mechanisms, energy management equipment, storage and regulation equipment, power conditioning equipment and power distribution protection and switching assemblies.

STRUCTURAL/MECHANICAL SUBSYSTEM

The Structural/Mechanical Subsystem includes:

A. The basic structure and all provisions for structural accommodation of a six-man crew, the spacecraft subsystems, and an experiment program.

B. Mechanical Equipment required for:

1. Docking with experiment or logistics modules
2. Space Station Access, including hatches, airlocks and viewports
3. Antenna and Solar Array Drive
4. Cargo handling and transfer
5. Extravehicular Activity Support

EXPERIMENT SUPPORT EQUIPMENT SUBSYSTEM

The Experiment support Equipment subsystem provides the Space Station system with a specific general purpose capability based on:

A. Requirements to support the defined experiment program and undefined experiments to be conducted during the five years following ISS activation.

B. Requirements to support the operation of the Space Station and its subsystems. These facilities will include shops and labs to repair, disassemble and assemble and calibrate subsystem equipment.

C. Requirements to support the separately launched experiment modules.

The equipment definition is based on identified requirements, but does not necessarily satisfy all of them. When actual support requirements develop, the support can be provided by carry-on equipment, etc. Experiment support equipment cost baseline includes only the specific capability defined.

The above experiment support equipment is not unique to an individual FPE but supports multiple FPE's as well as space station module support requirements. This support equipment is not limited to integral experiments.

WBS 75x98

INTEGRATION AND INSTALLATION

A. Production (recurring)

1. Manufacturing

a) Provide all material and miscellaneous fabrication for one flight article system assembly (from complete subsystems).

b) Assembly of one flight article (space station modules).

c) Provide quality assurance, production control, calibration and other support effort for assembly.

WBS 75x05

ENVIRONMENTAL CONTROL/LIFE SUPPORT SUBSYSTEM

The ECLS Subsystem includes the equipment which provides:

Atmosphere Supply and Control
Atmosphere Regeneration
Atmosphere Purification
Water Management
Waste Management
IVA/EVA Equipment
Thermal Control

INTEGRAL EXPERIMENTS (SPACE STATION PROJECT) (NASA FURNISHED COST DATA) (ISS)

Description

Integral Experiments consist of those individual FPE's from the Baseline Experiment Program 534G which are integral to the Space Station. Experiment support equipment required to adapt the experiment to the Space Station Modules is not included. This support equipment will be provided under the Experiment Integration WBS box.

Task Summary

A. DDT&E

Includes all design and development effort for each FPE.

B. Operations

Includes all effort for refurbishment updating and integration of experimenting to FPE level subsequent to the initial launch.

EXPERIMENT INTEGRATION (ISS)

Definition

Experiment Integration consists of those tasks and onboard experiment support equipment required to integrate the integral experiments with the Space Station modules. It includes experiments launched with the Station and those experiments planned for separate launch during the operational phase. It includes:

Design integration of interfaces, procedures and software.

Experiment support hardware for adapting experiments to the Space Station, including development and production effort. This experiment support equipment is unique to the integration task and the individual FPE.

Test integration using the FIT

Production integration of flight experiments

GSE integration where required

Integration tasks continuing after launch of the Space Station Modules will utilize the FIT for installation and checkout verification.

Work Breakdown

A. Design, Development, Test and Engineering

1. Initial Engineering

a. Support Interface Analysis and Design Coordination - This task assumes that a completely defined experiment related interface, including Experiment Support Equipment, Experiment Support, and accommodations by the other Space Station Subsystems, is provided and that this interface is the basis for the experiment design.

b. Design special experiment support equipment flight hardware required to accommodate each experiment.

c. Provide experiment integration, installation and check-out requirements, procedures, analysis and reports related to integration or development of flight experiment equipment with the FIT.

d. Provide installation and checkout requirements, procedures, analysis and reports related to integration of flight experiment equipment with the Space Station prior to launch and in orbit.

e. Design special test equipment and fixtures for experiment integration (non-flight hardware).

2. <u>Test Operations</u>

a. Conduct experiment support equipment development and qualification tests.

b. Conduct experiment integration activities on the FIT.

3. <u>Production Planning and Tooling</u>

a. Provide manufacturing engineering for production of onboard experiment support equipment and for installation and checkout of experiments.

b. Design and fabricate experiment handling fixtures and equipment.

c. Provide Production Planning.

B. <u>Production</u>

1. Manufacture special onboard experiment support equipment.

2. Install and checkout the onboard experiments and support equipment which are included in the vehicle at launch. Conduct integrated testing.

<u>Operations</u>

No Task - In-orbit installation of experiment equipment is included in flight operations.

LOGISTICS MODULE SYSTEM (ISS)

Definition

The Logistics Module (Log M) is a system utilized for Shuttle transport of cargo (exclusive of crewmen) and in-orbit storage of consumables in support of the Modular Space Station Program during the ISS phase.

Four Logistics Modules will be required. At least one remains in-orbit docked to the ISS, at all times after ISS activation.

Task Summary

A. DDT&E

Includes all effort for design and development of the Log M

- Initial Engineering
- Test Operations including two ground test vehicles
- Production planning and tooling

B. Production

Includes all effort to produce and deliver four Logistics Modules.

- Procurement
- Fabrication, assembly and test
- Production support
- Spares for in-plant and launch operations use

C. Operations

No Task - all effort is included in Launch Operations and Flight Operations WBS boxes.

WBS 369

GROUND SUPPORT EQUIPMENT (GSE) (ISS)

Definition

This WBS box includes all costs associated with providing GSE for the Space Station Project, including:

- Space Station Modules GSE
- Integral Experiments GSE
- Logistics Module GSE
- Launch Operations GSE
- Flight Operations GSE
- Test Articles GSE

The GSE for each of these systems is described in the individual WBS boxes. The costs cover all effort to design, develop, produce and deliver the required equipment or equipment modifications. Operations using the GSE are covered in other tasks. All GSE costs are considered DDT&E (non-recurring) since they would not recur for the launch of an additional Space Station.

Tasks

Development Engineering - Includes all engineering effort for GSE analysis, design, design support, development, test, manufacturing support, and GSE checkout or acceptance tests.

Test Operations - Includes all effort required to conduct development tests in support of GSE design. Such tests should be minimal. No qualifications testing will be done on GSE. Software development and validations are included in Space Station Modules (Level 4) test operations.

Production - Includes all effort for planning, tooling, procurement, fabrication, assembly, test and delivery of GSE items.

SPACE STATION MODULES GSE

Description

This WBS box includes all GSE which interfaces directly with Space Station modules hardware during checkout, acceptance test and delivery. It will also be utilized for prelaunch and launch operations where applicable. The GSE described is developed for use with the test and flight articles. Maximum use will be made of existing GSE, either as-is or modified. Equipment in the following categories is required.

A. Integrated Checkout Equipment which provides capability to perform system level testing of the clustered flight modules and the FIT. One set of equipment will be provided for use at the manufacturing location and will then be utilized for the FIT use. It will consist of approximately 20 standard electrical equipment cabinets plus interconnecting cables and umbilicals. Approximately 25% of this equipment will be required at the launch site to support processing of the flight modules after which it will be used by the FIT.
1 set.

B. Servicing equipment to provide fluids or expendables to the Space Station during checkout for thermal conditioning equipment, water management, cooling system, atmospheric supply and P/RCS propellants.
2 sets.

C. Access equipment for manned occupancy for both horizontal and vertical module orientation during ground checkout including lighting and ventilation kits, communications, cabling, and external stands and covers. 2 sets.

D. Handling and protection equipment for the Space Station modules, solar arrays, and major components and equipment. 3 sets.

E. Electrical GSE consisting of radar frequency interference test set, maintenance test sets, and general purpose electrical equipment.
2 sets.

F. Transportation equipment consisting of transporters, covers, restraints and environmental control for the Space Station module, and electrical power supply. 3 sets.

WBS 309

INTEGRAL EXPERIMENT GSE

Description

Experiment GSE is that equipment required to support experiments to be integrated into the Space Station Modules. It includes checkout, handling, shipping and servicing equipment. Equipment will be provided by the experiment contractor. Nature of the items will depend upon the particular experiment. One set of the peculiar GSE for each FPE will be required. Items provided for one experiment will be utilized on others where common requirements exist.

WBS 261

LOGISTICS MODULE GSE

Description

This WBS box includes Logistic Module unique equipment required for handling and checkout of the Logistics Module. (Servicing equipment is considered part of the Launch Operations GSE).

Handling and shipping equipment is required for delivery (air shipment) of modules, storage and transportation including dollies for four modules at KSC, and handling equipment for installing the module in the Space Shuttle orbiter.

Checkout equipment will be required for acceptance test and prelaunch checkout of the module.

WBS 279

LAUNCH OPERATIONS GSE

Description

Launch operations GSE includes modified or new equipment required for support of the Space Station and Logistic Modules or integrated experiments during preparation and launch, but which is not already included in GSE required for manufacture, handling and checkout.

These requirements will include launch equipment used for servicing of the Space Station or experiments, equipment for handling of pad-installed items, and for operation or monitoring during launch. Any Space Station peculiar control or monitoring during launch; and any Space Station peculiar control or monitoring consoles required in launch control for countdown monitoring will be included.

Also, included is sustaining logistics GSE for Space Station resupply and maintenance. This would include handling equipment for large replaceable items and servicing equipment for supplying expendables to the Logistics Module.

WBS 289

FLIGHT OPERATIONS GSE

Flight operations GSE includes any specialized equipment required to support planning, flight operations, communications, command and control of the Space Station, logistics provisioning, logistics modules, and installed experiments. Requirements should be minimal since use of existing capability will be designed for wherever possible. Ground network and synchronous satellite communications, command and control functions are excluded.

TEST ARTICLE GSE

Description

The set of electronic GSE used by the flight articles will be required for use with the FIT, which will be in operation preceding and following the Space Station Module Checkout and launch. It will be used to support the FIT and to develop the GSE interfaces and checkout and launch procedures. Supporting service and access equipment will also be required.

WBS 491

LAUNCH OPERATIONS

Definition

This WBS includes all contractor, NASA and support agency costs attributable to the KSC launch operations associated with the Space Station Project. It excludes similar effort attributable to the Space Shuttle systems or experiment modules. It includes site activation prior to Space Station delivery, all preparations and conduct of launch, and post-launch operations. It also includes inplant contractor support of the launch operations. All costs are in the Operations category.

A minimum cost philosophy will be followed appropriate for a one-time operation. This will consist of a task force approach with the majority of the launch operations crew made up from some of the personnel who have conducted assembly and checkout of the Space Station prior to delivery. These personnel will be on TDY to the launch site for approximately seven months.

Contractor Tasks

Includes contractor and subcontractor effort for Space Station elements and integral experiments. Consists of the following effort:

Launch Site Operations

Site Activation
Launch GSE Installation and Maintenance
Joining to Shuttle, Interface Check with Shuttle and Transportation to pad.
Pad Checkout
Countdown
Launch and Ascent
Post-Launch Deactivation

Total on-site contractor personnel for Space Station Project launch operations is an average of TBD for nine months of which TBD follow each module to the launch site and return to the factory after module launch. A sustaining group for module launches will be TBD personnel which could be common to all Shuttle payloads or returned to the factory after the third module launch.

Inplant Support

Effort required at the contractor's plants in direct support of launch operations including:

Engineering technical support

Administrative support

Manufacturing/Procurement support

NASA and Support Agency Tasks (costs excluded per NASA direction)

Includes NASA and range support agency activities in support of Space Station Project launch requirements. Consists of the following effort:

Overall management and administration

Support services - safety, security, transportation, communications, etc.

Data acquisition and processing services during checkout

Tracking communications, and monitoring of the Space Station during ascent and injection into orbit (part of the ground network operations).

Post-launch support for deactivation operations.

WBS 591

FLIGHT OPERATIONS

Definition

Flight operations consists of mission operations and mission operations support functions. Mission operations support if comprised of mission analysis and planning, flight operations support, experiment operations support, logistics operations support, and administration of NASA and Contractor operations. These operations are applicable to the Space Station, integral experiments and the attached and free-flying modular experiments which are controlled or monitored from the Space Station.

This WBS excludes basic costs of the logistic transportation system for delivery of personnel and resupply to and from orbit. These costs are in the Space Shuttle operations. Also not included are the flight crew training and equipment and the ground network for communications and tracking.

NASA Tasks (Costs excluded per NASA direction)

Mission Operations Support - Includes NASA effort required to administer the mission operations support function comprised of Mission Analysis Planning, Flight Operations Support, Experiment Operations Support and Logistics Operations Support. Included are:

- Administrative and Management Functions
- Project Planning and inter-program/agency planning

Mission Analysis and Planning - Includes the NASA effort required to administer the planning function for the Space Station project. This includes:

- Coordination with NASA Center, users, etc.
- Establishment of priorities
- Mission planning and scheduling direction
- Overall requirements of mission operations
- Establish Orbital Procedures Requirements (Users Handbook, etc.)

Flight Operations Support - Includes the NASA effort required to provide the real time ground support of the Space Station orbital operations and crew training. This includes:

Flight Control

Administration of Flight Operations function

Ground network provisioning and operations*

Data acquisition*

Hardware change authorization

Flight crew training (personnel and hardware provisioning)

Simulation and simulation provisioning

Data distribution**

Experiment Operations Support - Includes NASA effort required to provide real time ground support of Space Station orbital operations. This includes:

Coordination with user agencies and NASA Centers

Direction of experiment operations function

Real time data evaluation

Logistics Operations Support - Includes NASA effort required to replenish expendable supplies and equipment needed to maintain ground and orbital operations. This includes:

Management of Logistics Operations Support

Facility Operations

Procurement Administration

Inter and intra program coordination for logistics functions

Establishment of Shuttle schedules/availability/services for Space Station

Contractor Tasks

Mission Operations - The astronauts and PI's are provided by NASA, all hardware elements have been accounted for elsewhere and logistics operations support provides all consumables/replenishment.

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*Ground network costs provided by NASA.

**Hard copy data distributed by Logistics Operations support function. Soft data reduced and distributed as ground network costs provided by NASA.

Mission Operations Support - This is a NASA management task and includes no contractor functions. All contractor tasks are contained in the next functional level.

Mission Analysis and Planning - Includes Space Station contractor, experiment contractor and subcontractor effort required to provide the planning function for the Space Station project. This includes:

Mission Plans (including Timelines) generation and maintenance including long (10 yr) and short (90-day with 30-day incremental update for intermediate shuttle flights)
Schedules
Procedures (orbital operations handbook, etc.)
Configuration Authorization
SS Project interface with other programs/projects
Consultation with flight crew for system or experiments
Long term trend analysis
Logistics flight planning (including requirements to Shuttle Project)

Flight Operations Support - Includes the Space Station contractor effort required to provide the real time and near real time ground support of the Space Station orbital operations and crew training. This includes:

Support of Flight Control
Real Time Maintenance Operations Support
Real Time Orbital emergency support
Ground crew training (includes both flight control ground crew and launch operations ground crew) (See attached table)
Short term trend analysis

Experiment Support Operations - Includes experiment contractor effort required to provide real time ground support of Space Station orbital operations. This includes:

Experiment Coordination
Experiment Operations Planning Support
Experiment Support (GPL Equipment, EXP-SS Subsystem Compatibility)

Logistics Operations Support - Included Space Station and experiment contractor effort required to replenish expendables supplied and equipment needed to maintain ground and orbital operations. This includes:

Inventory Management and Maintenance
Configuration Management
Cargo Handling
Procurement
Testing
Logistics Module Maintenance Handling
Refurbishment and Support
Consumables Monitoring
Maintenance of Launch Operations, Mission Support GSE
Resupply of expendable items, spares and supplies to the Space Station
Mockups/FIT
Interface Control

FLIGHT OPERATIONS ATTACHMENT
OPERATIONS PERSONNEL TRAINING REQUIREMENTS

Personnel Description	Average Number Operational and Period	Total Recruitment	Average Duration Training Classroom/ O.J.T.
Astronaut/Flight Controller	Training provided by NASA		
Experiment Scientist	Provided in NASA furnished experiment costs		
P. I. Representative	Provided in NASA furnished experiment costs		
Flight Controller/ Mission Support	235/10.5 years	575	3 mo/6 mo

TEST ARTICLE "N"

Definition

This WBS item includes all contractor hardware costs attributable to the project/system level test articles required for the Space Station Project during the design or development phases. It excludes mockups, structure test vehicle and subsystems test articles. It includes restoration of available test components to functional condition, fabrication of structure, installation and wiring of subsystems and their assembly into a test article. Test operations using Test Article "N" are covered in the Space Station Modules (Level 4) WBS.

Test Requirements

- A flight test program and test article GSE will not be required.
- Test articles consist of a functional model (FM/ship set) and a flight integration tool (FIT/Integration Fixture).
- Subsystems needed for integration into the test articles will be the same hardware that is used in subsystem development and qualification tests. (See subsystem quantities tabulated under the Space Station Module Subsystems definition.)
- The FIT will also be utilized as a configuration verification tool for subsequent experiment/subsystems changeover and control.

WBS 82

Functional Model (FM Description)

The FM is a set of equipment used for integration of the Space Station Module subsystems and for development and integration of all onboard computer programs (onboard checkout, guidance and navigation, control, data management, etc.). It will consist of functional electronic subsystems with interfacing elements from other subsystems plus software and general purpose nondedicated computing capability. The Logistics Modules also utilize a Functional Model for development.

The subsystem equipments will be assembled on a laboratory arrangement or racks suitable for functional hookup and access for development. No primary flight type structure is required.

Flight Integration Tool (FIT) Description

The FIT is a flight configuration Space Station Module. It will contain all subsystems in their flight configuration except for some items which will be replaced by substitute items suitable for the ground test role and with the addition of provisions required for 12 years of operations on the ground.

It is used initially to develop and verify the installation and operation of the subsystems. After the subsystems are operating it will be used to verify the installation and interfaces of the integral experiments.

After launch the FIT will continue to be used for integration of experiments and for checkout of subsystem modifications which are to be installed in orbit.

Contractor Tasks

Fabrication - Includes Space Station Module contractor and subsystem/assembly subcontractors. Where subsystems/assemblies previously fabricated under the Space Station Module design and development activities are to be utilized in a dual role, no fabrication task is required. However, restoration of these subsystems/assemblies to functional condition is included. (See Table of quantities under the Space Station Module Subsystems definition).

Assembly - Includes Space Station Module contractor assembly of Test Article "N".

SYSTEM SUPPORT

Definition

This WBS item includes all contractor costs attributable to Systems Support for the Space Station Project during design, development, production and operations. System Support includes initial system engineering, engineering integration, all sustaining engineering and production checkout engineering. System Integration encompasses these functions for the Space Station Modules. System support relates the Space Station Modules to the rest of the Space Station Project systems.

Excluded is NASA Technical and engineering effort in support of the Space Station Project. It is included in NASA Program Level System Support.

Design, Development, Test and Engineering (non-recurring)

System Engineering - includes the initial system analysis to define Space Station Project requirements.

System analysis of performance and operations requirements
Special studies and trade studies
System cost-effectiveness evaluation
Interface requirements definition

Engineering Integration - Covers integration of engineering effort during initial design, development and qualification. This consists of engineering functions which are not directly for design and development of the individual flight hardware and GSE end items, but which are required as part of the overall engineering effort. This includes:

Design and development plans and schedules
Interface control
Test and checkout integration and plans
Design performance evaluation
Engineering configuration control

Effectiveness Engineering -

Reliability
Maintainability
Safety
Human Factors
Value Engineering

Production (recurring)

Engineering Integration - Continued integration of the overall engineering effort during production and acceptance test of flight hardware and GSE. Includes:

Monitoring and control of change requirements
Interface coordination
Analysis of design, manufacturing and checkout performance

Effectiveness Engineering - Sustaining effort to monitor changes and production operations.

Sustaining Engineering - Includes all engineering effort in support of flight hardware and GSE production, plus other required (Class 2) changes after initial release of production drawings. This includes:

Engineering analysis and design changes
Support of fabrication and assembly requirements

Production Checkout Engineering - Includes engineering effort to conduct factory checkout and acceptance tests of the Logistic Module, Space Station Project orbital system and supporting GSE. (Manufacturing effort in support of checkout is covered in the Logistic Module [Level 4] WBS box.)

Operations (recurring)

Engineering Integration - Continued engineering integration effort during launch and flight operations phases, including:

Monitoring and control of engineering changes
Analysis of operations performance data
Interface coordination

Effectiveness Engineering - Analysis in support of operations requirements.

Sustaining Engineering - Engineering analysis and design changes (Class 2) required during launch and flight operations, including:

- Design changes to Space Station Project systems
- Design changes to GSE
- Changes required to accommodate experiments

FACILITIES

Definition

This WBS includes all contractor, NASA and support agency costs attributable to modifying, leasing, designing, fabricating or performing site exploration (civil engineering) for an industrial or government facility required by the Space Station Project during design, development, production or launch/flight operations except those provided by the Ground Network and synchronous satellite communication institutional base and those provided by NASA for crew training.

Facility Descriptions

Contractor development and production operations will utilize minor modifications to existing industrial facilities for access and services requirements of the Space Station.

Government facilities for launch and flight operations support will include:

1. Vertical Assembly Low Bays - Modifications to four existing unused low bays for servicing, processing and loading of the Logistics Module.
2. Logistics Building - Modification of an existing hangar type building (Shipping & Receiving Building) for logistics supply functions including stocking of Space Station supplies and storage.
3. Manned Spaceflight Operations Building - Modification of high pay area in the existing facility to accommodate the FIT and ancillary equipment for experiment integration. The FIT may be located elsewhere but is identified here to identify representative facility mods.
4. Mission Support Center - Modification of existing facilities (e.g., MCC-Houston for use in support of resupply operations and orbital operations.

Contractor Tasks (DDT&E/Non-recurring)

- Prepare facility criteria for industrial modifications or leases, includes Space Station Project contractor and subcontractors.
- Design, modify or lease industrial facilities
- Prepare interfacing facility criteria for government facilities

NASA and Support Agency Tasks (DDT&E/Non-recurring)

- Design and modify required government facilities in the launch, mission control, or recovery areas.

PROJECT MANAGEMENT

Definition

Project Management includes all contractor effort for management of the Space Station Project elements, including the integral experiment items. It covers all general management functions, including the management of technical effort, but does not include system engineering or other technical tasks which are covered in the System Support WBS box.

Excludes NASA Project Management effort in support of the Space Station Project.

This effort, as defined below, continues through DDT&E, Production and Operations phases.

Contractor Tasks

Contractor Project Management functions include the following:

- Program Planning and scheduling
- Financial Planning and Control
- Configuration Management
- Production and Procurement Management
- Test Operations Management
- Quality Assurance Management
- Logistics Support Management
- Engineering Management, including administration and engineering business systems and support functions.
- Contract and Documentation Management

RESEARCH AND APPLICATIONS MODULES PROJECT (ISS & GSS)

The RAM Project consists of all separately launched RAM Modules which carry experiments that are not integrated in the Space Station. Effort included in this project covers DDT&E, Production and Operations tasks to design, develop, produce and operate these experiments and modules.

The Baseline Program (534G) assumes that the following items are included in the RAM Project:

- 3 Free flying modules
- 11 attached modules (3 are reworked) for a total of 14 attached module launches.
- 17 FPE's

SPACE STATION PROGRAM

(MODULAR)

COST ESTIMATING GROUNDRULES

APPENDIX B

COST ESTIMATE DATA FORM A

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COST ESTIMATE DATA FORM A
(1972 DOLLARS IN MILLIONS)

X NON-RECURRING (DDT&E)
RECURRING (PRODUCTION)
RECURRING (OPERATIONS)

WBS IDENT. NUMBER	WBS ITEM NAME	WBS ITEM COST	NUMBER OF UNITS	REFER. UNIT	LEARN. INDEX	T D	T S	SPREAD FUNCTION	MILESTONE DATE (GFY)
1	SS PROGRAM	3548.0	1	1	100	174	66	0	9 - 81
31	RAM PROJ	185[illegible].0	1	1	100	167	59	0	9 - 81
21	SS PROJECT	1693.0	1	1	100	135	66	0	9 - 81
21	SS PROJ ISS	1245.6	1	1	100	108	66	0	9 - 81
21034	PROJ MGMT	56.7	1	1	100	108	66	70	9 - 81
21052	EXPM INTEG	95.6	1	1	100	96	54	50	9 - 81
21064	SYS SUPP	49.8	1	1	100	108	66	70	9 - 81
21081	FIT ART	117.9	1	1	100	27	48	5[illegible]	9 - 81
21082	FM ART	42.5	1	1	100	18	47	65	9 - 81
21089	TEST ART	160.4	1	1	100	27	48	0	9 - 81
21124	(5) FACIL	28.1	1	1	100	59	66	70	9 - 81
21261	LOG M GSE	14.0	1	1	100	56	58	40	9 - 81
21269	(5) SS GSE	26.7	1	1	100	52	60	40	9 - 81
21279	LAUNCH GSE	1.5	1	1	100	48	59	40	9 - 81
21289	FLIGHT GSE	14.0	1	1	100	48	56	40	9 - 81
2129[illegible]	TST AR GSE	0.0	1	1	100	0	0	65	9 - 81
21309	EXPMT GSE	37.2	1	1	100	96	60	50	9 - 81
21369	TOTAL GSE	93.4	1	1	100	96	60	0	9 - 81
21751	POWER MODL	212.2	1	1	100	57	66	70	9 - 81
21752	CREW MODUL	131.9	1	1	100	57	65	70	9 - 81
21753	GPL MODULE	109.2	1	1	100	57	64	70	9 - 81
21758	TOT S/SYS	453.4	1	1	100	52	66	60	9 - 81
21759	SS INTEGR	111.0	1	1	100	58	66	70	9 - 81
21760	SS MODULES	564.4	1	1	100	59	66	0	9 - 81
21761	LOG MODUL	41.6	1	1	100	49	52	50	9 - 81
219[illegible]	EXPERMT N	156.1	1	1	100	108	66	50	9 - 81
2112401	MFG FACIL	11.2	1	1	100	59	66	70	9 - 81
2112402	TEST FACIL	.0	1	1	100	59	66	70	9 - 81
2112403	LNCH FACIL	11.2	1	1	100	59	66	70	9 - 81
2112404	M/C FACIL	5.6	1	1	100	59	66	70	9 - 81
2112405	MSFN FACIL	.0	1	1	100	59	66	70	9 - 81
2126902	INTC/O GSE	11.2	1	1	100	52	60	40	9 - 81
2126905	ELECT GSE	1.1	1	1	100	52	60	40	9 - 81
2126923	SERVCE GSE	10.7	1	1	100	52	60	40	9 - 81
2126924	ACCESS GSE	.9	1	1	100	52	60	40	9 - 81
2126956	HANDLE GSE	1.1	1	1	100	52	60	40	9 - 81
21269[illegible]6	TRANSP GSE	1.3	1	1	100	52	60	40	9 - 81
21269[illegible]7	MISCL GSE	.3	1	1	100	52	60	40	9 - 81
2175101	PWR INTEGR	.0	1	1	100	45	66	5[illegible]	9 - 81
2175102	STRU/MECH	29.2	1	1	100	41	66	60	9 - 81

COST ESTIMATE DATA FORM A
(1972 DOLLARS IN MILLIONS)

X NON-RECURRING (DDT&E)
RECURRING (PRODUCTION)
RECURRING (OPERATIONS)

WBS IDENT. NUMBER	WBS ITEM NAME	WBS ITEM COST	NUMBER OF UNITS	REFER. UNIT	LEARN. INDEX	T D	T S	SPREAD FUNCTION	MILESTONE DATE (GFY)
2175105	EC&LS	29.5	1	1	100	50	66	60	9 - 81
2175107	COMM	10.9	1	1	100	52	66	60	9 - 81
2175123	PROP/RCS	7.6	1	1	100	47	66	60	9 - 81
2175124	ELE POWR SOLAR	84.2	1	1	100	57	66	60	9 - 81
2175146	GUID & NAV	4.6	1	1	100	52	66	60	9 - 81
2175147	DATA MGMT	14.1	1	1	100	52	66	60	9 - 81
2175156	STAB & A/C	26.3	1	1	100	51	66	60	9 - 81
2175157	OBC&FI	4.8	1	1	100	51	66	60	9 - 81
2175159	CRW HABIT	1.2	1	1	100	56	66	60	9 - 81
2175201	CREW INTEGR	.0	1	2	100	45	65	55	9 - 81
2175202	STRU/MECH	8.3	1	2	100	41	65	60	9 - 81
2175205	EC&LS	41.1	1	2	100	50	65	60	9 - 81
2175207	COMM	27.8	1	2	100	52	65	60	9 - 81
2175223	PROP/RCS	10.7	1	2	100	47	65	60	9 - 81
2175224	ELE POWR	4.7	1	2	100	57	65	60	9 - 81
2175247	DATA MGMT	21.5	1	2	100	52	65	60	9 - 81
2175256	STAB & A/C	2.0	1	2	100	51	65	60	9 - 81
2175257	OBC&FI	4.7	1	2	100	51	65	60	9 - 81
2175259	CRW HABIT	11.3	1	2	100	56	65	60	9 - 81
2175301	GPL INTEGR	.0	1	3	100	45	64	55	9 - 81
2175302	STRU/MECH	20.9	1	3	100	41	64	60	9 - 81
2175305	EC&LS	23.7	1	3	100	50	64	60	9 - 81
2175307	COMM	.1	1	3	100	52	64	60	9 - 81
2175324	ELE POWR SOLAR	5.0	1	3	100	57	64	60	9 - 81
2175339	EXP SUP EQ	15.3	1	1	100	50	66	60	9 - 81
2175347	DATA MGMT	35.6	1	3	100	52	64	60	9 - 81
2175356	STAB & A/C	.3	1	3	100	51	64	60	9 - 81
2175357	OBC&FI	6.1	1	3	100	51	64	60	9 - 81
2175359	CRW HABIT	2.2	1	3	100	56	64	60	9 - 81
2175802	STRU/MECH	58.0	1	1	100	43	66	60	9 - 81
2175805	EC&LS	94.0	1	1	100	52	66	60	9 - 81
2175807	COMM	39.0	1	1	100	54	66	60	9 - 81
2175823	PROP/RCS	19.0	1	1	100	48	66	60	9 - 81
2175824	ELE POWR	94.0	1	1	100	57	66	60	9 - 81
2175839	EXP SUP EQ	15.0	1	1	100	50	66	60	9 - 81
2175846	GUID & NAV	5.0	1	1	100	52	66	60	9 - 81
2175847	DATA MGMT	71.0	1	1	100	54	66	60	9 - 81
2175856	STAB & A/C	29.1	1	1	100	53	66	60	9 - 81
2175857	OBC&FI	16.0	1	1	100	53	66	60	9 - 81
2175859	CRW HABIT	14.7	1	1	100	58	66	60	9 - 81

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COST ESTIMATE DATA FORM A
(1972 DOLLARS IN MILLIONS)

NON-RECURRING (DDT&E)
X RECURRING (PRODUCTION)
RECURRING (OPERATIONS)

WBS IDENT. NUMBER	WBS ITEM NAME	WBS ITEM COST	NUMBER OF UNITS	REFER. UNIT	LEARN. INDEX	T D	T S	SPREAD FUNCTION	MILESTONE DATE (GFY)
5	SS PROGRAM	943.0	1	1	100	133	47	0	9 - 81
35	RAM PROJ	251.0	1	1	100	133	47	0	9 - 81
25	SS PROJECT	692.0	1	1	100	105	36	0	9 - 81
25	SS PROJ IS[illegible]	380.0	1	1	100	78	36	0	9 - 81
25034	PROJ MGMT	18.0	1	1	100	78	36	0	9 - 81
25064	SYS SUPP	30.4	1	1	100	78	36	0	9 - 81
25751	POWER MODL	76.6	1	1	94	37	43	50	9 - 81
25752	CREW MODUL	73.2	1	1	94	37	42	50	9 - 81
25753	GPL MODULE	50.4	1	1	94	37	41	50	9 - 81
25758	TOT S/SYS	200.0	1	1	94	39	43	45	9 - 81
25759	SS INTEGR	94.4	1	1	100	40	36	45	9 - 81
25760	SS MODULES	294.4	1	1	100	39	43	0	9 - 81
25761	LOG MODUL	36.5	1	1	100	32	34	40	9 - 81
259[illegible]	EXPERMT N	0.0	1	1	100	108	6[illegible]	80	9 - 81
2575101	PWR INTEGR	24.5	1	1	100	37	43	45	9 - 81
2575102	STRU/MECH	7.4	1	1	82	15	43	40	9 - 81
2575105	EC&LS	7.5	1	1	90	15	37	40	9 - 81
2575107	COMM	2.7	1	1	90	14	35	40	9 - 81
2575123	PROP/RCS	3.5	1	1	92	12	36	40	9 - 81
2575124	ELE POWR SOLAR	23.2	1	1	95	20	38	40	9 - 81
2575146	GUID & NAV	.5	1	1	95	13	31	40	9 - 81
2575147	DATA MGMT	2.6	1	1	90	16	37	40	9 - 81
2575156	STAB & A/C	2.9	1	1	95	15	34	40	9 - 81
2575157	OBC&FI	1.3	1	1	90	13	36	40	9 - 81
2575159	CRW HABIT	.5	1	1	90	12	32	40	9 - 81
2575201	CREW INTEGR	23.8	1	2	100	37	42	45	9 - 81
2575202	STRU/MECH	4.5	1	2	82	15	42	40	9 - 81
2575205	EC&LS	7.2	1	2	90	15	36	40	9 - 81
2575207	COMM	7.0	1	2	90	14	34	40	9 - 81
2575223	PROP/RCS	4.9	1	2	92	12	35	40	9 - 81
2575224	ELE POWR SOLAR	2.9	1	2	95	20	37	40	9 - 81
2575247	DATA MGMT	4.0	1	2	90	16	36	40	9 - 81
2575256	STAB & A/C	12.9	1	2	95	15	33	40	9 - 81
2575257	OBC&FI	1.2	1	2	90	13	35	40	9 - 81
2575259	CRW HABIT	4.8	1	2	90	12	32	40	9 - 81
2575301	GPL INTEGR	18.1	1	3	100	37	41	45	9 - 81
2575302	STRU/MECH	5.8	1	3	82	15	41	40	9 - 81
2575305	EC&LS	5.7	1	3	90	15	35	40	9 - 81
2575307	COMM	.2	1	3	90	14	34	40	9 - 81

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COST ESTIMATE DATA FORM A
(1972 DOLLARS IN MILLIONS)

  NON-RECURRING (DDT&E)
X RECURRING (PRODUCTION)
  RECURRING (OPERATIONS)

WBS IDENT. NUMBER	WBS ITEM NAME	WBS ITEM COST	NUMBER OF UNITS	REFER. UNIT	LEARN. INDEX	T D	T S	SPREAD FUNCTION	MILESTONE DATE (GFY)
2575324	ELE POWR SOLAR	3.0	1	3	95	20	36	40	9 - 81
2575339	EXP SUP EQ	7.6	1	1	100	13	37	40	9 - 81
2575347	DATA MGMT	7.0	1	3	90	16	35	40	9 - 81
2575356	STAB & A/C	[illegible].0	1	3	95	15	3[illegible]	40	9 - 81
2575357	OBC&FI	1.6	1	3	90	13	34	40	9 - 81
2575359	CRW HABIT	1.2	1	3	90	12	31	40	9 - 81
2575801	MODL INTEG	6[illegible].[illegible]	1	1	10[illegible]	39	43	45	9 - 81
2575802	STRU/MECH	18.0	1	1	82	17	43	0	9 - 81
2575805	EC&LS	20.0	1	1	90	17	37	40	9 - 81
2575807	COM	10.0	1	1	90	16	35	40	9 - 81
2575823	PROP/RCS	8.0	1	1	92	13	36	40	9 - 81
2575824	ELE POWR	29.0	1	1	95	2[illegible]	38	40	9 - 81
2575839	EXP SUP EQ	8.0	1	1	100	13	37	40	9 - 81
2575846	GUID & NAV	1.0	1	1	95	13	31	40	9 - 81
2575847	DATA MGMT	14.0	1	1	90	18	37	40	9 - 81
2575856	STAB & A/C	15.9	1	1	95	17	34	40	9 - 81
2575857	OBC&FI	4.0	1	1	90	15	36	40	9 - 81
2575859	CRW HABIT	6.8	1	1	90	14	32	40	9 - 81

DATE NOV 10, 1971
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COST ESTIMATE DATA FORM A
(1972 DOLLARS IN MILLIONS)

NON-RECURRING (DDT&E)
RECURRING (PRODUCTION)
X RECURRING (OPERATIONS)

WBS IDENT. NUMBER	WBS ITEM NAME	WBS ITEM COST	NUMBER OF UNITS	REFER. UNIT	LEARN. INDEX	T_D	T_S	SPREAD FUNCTION	MILESTONE DATE (GFY)
7	SS PROGRAM	1995.0	1	1	100	159	45	0	9 - 81
37	RAM PROJ	275.0	1	1	100	131	21	0	9 - 81
87	SHUTTLE OPS	513.0	1	1	100	120	6	0	9 - 81
27	SS PROJECT	1207.0	1	1	100	159	45	0	9 - 81
27	SS PROJ ISS	619.6	1	1	100	99	45	0	9 - 81
27034	PROJ MGMT	28.5	1	1	100	78	24	0	9 - 81
27052	EXPM INTEG	.0	1	1	100	72	30	0	9 - 81
27064	SYS SUPP	87.6	1	1	100	78	24	0	9 - 81
27081	(5) FIT	55.5	1	1	100	44	36	0	9 - 81
27089	TEST ART	55.5	1	1	100	44	36	0	9 - 81
27491	LAUNCH OPS	53.9	1	1	100	99	45	0	9 - 81
27591	FLIGHT OPS	230.3	1	1	100	99	45	0	9 - 81
27751	POWER MODL	52.9	1	1	100	35	28	0	9 - 81
27752	CREW MODUL	52.7	1	1	100	35	27	0	9 - 81
27753	GPL MODULE	30.1	1	1	100	35	26	0	9 - 81
27758	TOT S/SYS	135.6	1	1	100	12	23	0	9 - 81
27759	SS INTEGR	20.4	1	1	100	68	26	0	9 - 81
27760	SS MODULES	156.0	1	1	100	70	28	0	9 - 81
27761	LOG MODUL	7.8	1	1	100	57	13	0	9 - 81
2775101	PWR INTEGR	.0	1	1	A00	35	28	0	9 - 81
2775102	STRU/MECH REP SP	.1	1	1	100	26	28	0	9 - 81
2775105	EC&LS SPARES	9.7	1	1	100	10	23	0	9 - 81
2775107	COMM SPARES	3.3	1	1	100	13	22	0	9 - 81
2775123	PROP/RCS SPARES	2.9	1	1	100	12	25	0	9 - 81
2775124	ELE POWR SPARES	27.6	1	1	100	17	18	0	9 - 81
2775146	GUID & NAV SPARES	.5	1	1	100	12	19	0	9 - 81
2775147	DATA MGMT SPARES	3.1	1	1	100	29	22	0	9 - 81
2775156	STAB & A/C SPARES	4.2	1	1	100	10	20	0	9 - 81
2775157	OCS&FI SPARES	1.0	1	1	100	16	24	0	9 - 81
2775159	CRW HABIT SPARES	.4	1	1	100	18	21	0	9 - 81
2775201	CREW INTEGR	.0	1	2	100	35	27	0	9 - 81
2775202	STRU/MECH REP SP	.1	1	2	100	26	27	0	9 - 81
2775205	EC&LS SPARES	9.7	1	2	100	10	22	0	9 - 81
2775207	COMM SPARES	7.4	1	2	100	13	21	0	9 - 81
2775223	PROP/RCS SPARES	5.0	1	2	100	12	24	0	9 - 81
2775224	ELE POWR SPARES	3.5	1	2	100	17	17	0	9 - 81

DATE NOV 10, 1971
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COST ESTIMATE DATA FORM A
(1972 DOLLARS IN MILLIONS)

NON-RECURRING (DDT&E)
RECURRING (PRODUCTION)
X RECURRING (OPERATIONS)

WBS IDENT. NUMBER	WBS ITEM NAME	WBS ITEM COST	NUMBER OF UNITS	REFER. UNIT	LEARN. INDEX	T D	T S	SPREAD FUNCTION	MILESTONE DATE (GFY)
2775247	DATA MGMT SPARES	4.0	1	2	100	29	21	0	9 - 81
2775256	STAB & A/C	17.7	1	2	100	10	19	0	9 - 81
2775257	OCS&FI SPARES	1.0	1	2	100	16	23	0	9 - 81
2775259	CRW HABIT SPARES	4.4	1	2	100	18	20	0	9 - 81
2775301	GPL INTEGR	.0	1	3	100	35	26	0	9 - 81
2775302	STRU/MECH REP SP	.1	1	3	100	14	26	0	9 - 81
2775305	EC&LS SPARES	9.7	1	3	100	10	21	0	9 - 81
2775307	COMM SPARES	.2	1	3	100	13	20	0	9 - 81
2775324	ELE POWR SPARES	3.5	1	3	100	18	17	0	9 - 81
2775339	EXP SUP EQ SPARES	7.2	1	1	100	16	25	0	9 - 81
2775347	DATA MGMT SPARES	7.1	1	3	100	29	20	0	9 - 81
2775356	STAB & A/C SPARES	.2	1	3	100	10	19	0	9 - 81
2775357	OCS&FI SPARES	1.0	1	3	100	16	22	0	9 - 81
2775359	CRW HABIT SPARES	1.1	1	3	100	18	19	0	9 - 81
2775802	STRU/MECH	.2	1	1	100	28	28	0	9 - 81
2775805	EC&LS	30.0	1	1	100	12	23	0	9 - 81
2775807	COMM	10.0	1	1	100	15	22	0	9 - 81
2775823	PROP/RCS	8.0	1	1	100	13	25	0	9 - 81
2775824	ELE POWR	34.0	1	1	100	19	18	0	9 - 81
2775839	EXP SUP EQ	7.0	1	1	100	16	25	0	9 - 81
2775846	GUID & NAV	.2	1	1	100	12	19	0	9 - 81
2775847	DATA MGMT	14.0	1	1	100	31	22	0	9 - 81
2775856	STAB & A/C	22.1	1	1	100	12	20	0	9 - 81
2775857	OCS&FI	3.0	1	1	100	18	24	0	9 - 81
2775859	CRW HABIT	5.9	1	1	100	20	21	0	9 - 81